Concrete

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Relation of Voids in Aggregate to Strength of Concrete

A Discussion of Some Fundamental Principles in Making Good Concrete and Their Relation to the Cost and Strength

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IN order to point out the effect of the use of aggregates of certain qualities in improving concrete, it seems desirable to discuss, nontechnically, some of the fundamental considerations involved in the economical use of concrete materials. Most of you are familiar with these fundamental principles, but by presenting them, perhaps in a slightly different way, their vital importance may be more forcibly brought out.

The term "Better Concrete" should be understood to mean the desired strength for the least possible cost. Compressive strength will be used in this discussion as the measure of quality because concrete is largely used for purposes in which compressive strength is required and because it has been well demonstrated that flexural strength, surface hardness and resistance to alkalis bear well defined general relations to the compressive strength. Compressive strength is easy to determine. Large numbers of tests can be made for a moderate expenditure.

In securing high strength at low cost it is necessary to bear in mind that cement is, relatively, the most expensive ingredient in concrete. Pound for pound it costs probably about five times as much as sand and rock. This differential in cost between cement and aggregate suggests that any change in design which will maintain a given strength and reduce the quantity of cement is desirable. From another viewpoint, any improvement in the design of concrete which will increase the strength without increasing the quantity of cement is of equal value. In the design and construction of pavements, it is not possible to anticipate all of the stresses and destructive forces to which concrete will be subjected and we, therefore, strive to secure the maximum possible strength without increased cost of cement.

That this result is being accomplished wherever there is careful, scientific supervision of the work, is now a matter of general knowledge. Two thousand pound to 2500 pound twenty-eight day concretes have, in the past, been considered satisfactory. In some localities, such strengths are still the rule, but in our work, and on other work similarly conducted, due to the cooperation of engineers, contractors and material men, there is little difficulty in securing 3500 pound to 5000 pound concretes with the same amount of cement as was formerly used.

Sometimes the requirements of our modern specifications may seem unnecessarily precise. There is nothing new in the principles which we are applying, but the methods of application may differ from those used in other places.

Much has been said and written in recent years regarding the phenomenon that strength in concrete bears a general relation to the amount of water used to produce workable concrete. Variations in quantity of mixing water are an effect rather than a cause and in giving too much consideration to this effect, there may be a tendency to lose sight of the causes producing it. In the illustrations hereinafter used, it will be assumed throughout that the quality of the aggregate is uniform and that enough water is used to produce workable concrete with approximately a 1-inch slump (the present practice in highway paving work in this state).

Effect of Aggregate Grading on Voids

Figure Number 1 shows the effect of grading of aggregate in concrete. Typical cross-section views are included, first, of concrete made with voids of 45 per cent in both sand and rock; second, of concrete with 45 per cent of voids in sand and 35 per cent voids in rock, and third, of concrete with 35 per cent voids in both sand and rock. It has been found by experimenters that the minimum voidage for spheres of one size is approximately 44 per cent regardless of the size of the spheres. It is not unusual to secure coarse aggregate containing voids as high as 45 per cent (in loose material) and very well graded coarse aggregate is sometimes secured with voids as low as 35 per cent. Sand likewise shows voids varying between 35 per cent and 45 per cent according to grading and shape of particles. The examples as shown are, therefore, well within the range of probabilities of concrete construction work.

Almost invariably in practice, high voidage in sand is found to be associated with a sand consisting mostly of fine particles. Another undesirable characteristic of fine sand is that the surface area to be coated with cement increases very rapidly as the size of the particles is decreased. It has been shown that sand consisting entirely of $\frac{1}{4}$-inch particles would have a surface area of 518 square yards for each cubic yard of sand. Twenty-mesh sand has an area of 3325 square yards and fifty-mesh sand of over 10,000 square yards. This condition has long been taken into consideration in the design of asphaltic mixtures, but has often been lost sight of in the design or preparation of concrete mixtures.

Referring again to Figure 1 in Concrete Number 1, we find a large area between the rock particles which must be filled with mortar. The sand being poorly graded and having a high surface area, requires additional cement to fill the voids between the particles and to coat their surfaces. In this figure, an attempt has been made to show concretes of approximately the same strength, and in order to secure adequate mortar strength in this concrete, it is necessary to use a 1-1.8 mortar.

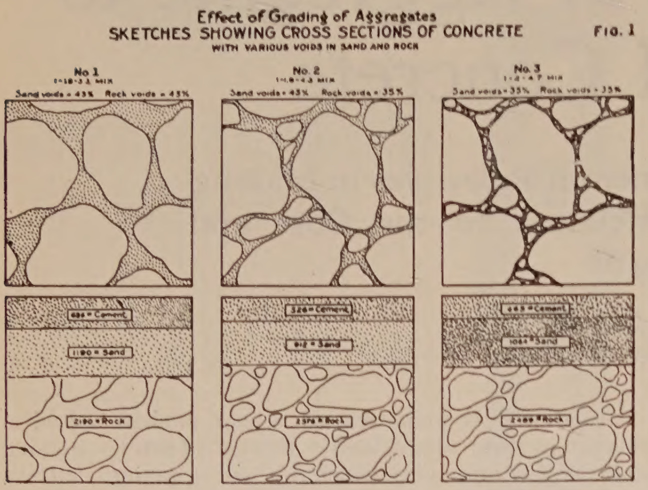
Effect of Grading of Aggregates
SKETCHES SHOWING CROSS SECTIONS OF CONCRETE
WITH VARIOUS VOIDS IN SAND AND ROCK
FIG. 1
No 1
1-1.8-3.3 MIX
Sand voids = 43% Rock voids = 43%
No. 2
1-1.8-4.3 MIX
Sand voids = 43% Rock voids = 35%
No. 3
1-2-4.7 MIX
Sand voids = 35% Rock voids = 35%
694 = Cement
1190 = Sand
2190 = Rock
326 = Cement
912 = Sand
2370 = Rock
465 = Cement
1084 = Sand
2400 = Rock

Figure 1

In Concrete Number 2, the sand is of the same inferior grading and the same richness of mortar is, therefore, required. In Concrete Number 2, however, it will be noted that smaller pieces of rock fill a considerable portion of the space between the larger rock particles. The rock, in this case, is well graded from fine to coarse and in thus using well graded rock, the volume of mortar required is greatly reduced.

In Concrete Number 3, a well graded sand is used. The larger particles of the sand are next in size to the smaller particles of the rock. The sketch is intended to show the manner in which these coarser sand particles decrease the area to be filled with fine sand and cement and they also greatly decrease the surface area to be coated with cement. Using a coarse sand in proportions of one part of cement to two parts of sand will give as great or probably a greater strength than can be had with the richer mortar used in Concretes Number 1 and Number 2.

The lower part of Figure Number 1 shows the component parts of one cubic yard of concrete of each of the different mixtures, workability remaining approximately constant.

It will be seen that Concrete Number 1 contains nearly 50 per cent more cement than Concrete Number 3. In this case, proper grading of material has resulted in displacing 230 pounds of cement with approximately the same amount of sand and gravel. This displacing of expensive cement with inexpensive sand and gravel has a very appreciable effect on the cost of concrete as is shown by Table Number 1. Between Concrete Number 1 and Number 3 this saving can easily amount to $4,000 per mile.

TABLE 1

COST OF MATERIALS

Cement $3.00 per bbl. Sand $2.00 per ton. Rock $2.40 per ton

Material	No. 1 Concrete	No. 2 Concrete	No. 3 Concrete
Cement	$5.47	$4.20	$3.48
Sand	1.19	0.91	1.07
Rock	2.62	3.09	2.99
Total per cu. yd. concrete	$9.28	$8.20	$7.54
Per mile of pavement—2330 cu. yd.	$21,344.00	$18,860.00	$17,342.00

Figure Number 2 shows graphically the cost per cubic yard of materials in Concretes Number 1, Number 2 and Number 3.

In the preparation of specifications for concrete materials limits of grading are specified as a means to an end. It has been found by experimentation that certain gradings are associated with low percentages of voids in ordinary materials. Void determinations have, in the past, been considered as rather difficult to make in the field and the practice has grown up of specifying the grading which is expected to produce low voidage rather than to specify the percentage of voids desired. This usual method, while having the merit of providing a simple screen test, is open to the objection that it does not always insure low voidage.

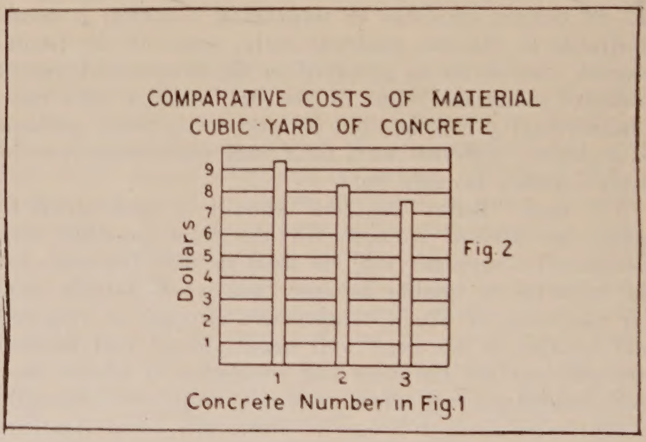

Figure 2

Samples of screened gravel have been tested in our laboratory within the last year which, when graded to theoretical maximum density grading, still contained approximately 55 per cent of voids. This was due to the shape of the particles, and grading specifications in this case failed utterly in securing desired low voidage in the material. Usually, however, a uniform grading of particles from fine to coarse results in low percentage of voids and low surface area.

It is quite likely that the wide variation in specified gradings of sand and rock found in different specifications is due to different results obtained with different materials by investigators who were attempting to secure gradings which would give low voids. Engineers sometimes lose sight of the fact that the real object to be attained is to secure the lowest possible voidage in the quarry or pit product.

Table Number 2 shows the quantity of material per mile of pavement for Concretes Number 1, 2 and 3 in Figure 1. From this table it will be seen that the use of the better graded material results in substituting approximately 250 tons per mile of rock and sand for an equal amount of cement. In other words, proper grading would result in about 6 per cent more sand and rock being used.

TABLE 2.
QUANTITY OF MATERIAL
TONS PER MILE OF PAVEMENT
(2300 Cubic Yards)
CONCRETE

Material	No. 1	No. 2	No. 3
Cement	780	605	534
Sand	1350	1050	1223
Rock	2490	2965	2862
Rock and sand combined	3840	4015	4085

NOTE.—This table assumes that concrete of equal density can be obtained. It is difficult to secure a high degree of density with poorly graded material as used in Number 1 Concrete. With lower density the quantity of material used would be slightly less and material would be replaced by air voids in concrete.

Effect of Aggregate Grading on Strength

Thus far, the matter has been considered entirely on the basis of assuming that more cement can and will be used to secure a given strength. Instead of increasing cement because of poorly graded aggregate, it is much more usual, where the use of such aggregate is permitted, to accept greatly reduced strengths.

The matter will now be discussed on the theory that the amount of cement to be used remains constant. In this case, improvement in the grading of the aggregate will be reflected by increased strength in the concrete. With a sand in which the particles, both fine and coarse, are of equal soundness and structural qualities, the mortar strength increases very rapidly with decreased voidage.

Figure 3 shows the results of tests in our laboratory with natural sand consisting almost entirely of water-worn particles of silica. In this case, variation from 44 per cent voids to 38 per cent voids resulted in an increased mortar strength of nearly 3000 pounds per square inch. In concrete with this same material, the increased mortar strength due to 6 per cent lower voids would be reflected by an increase of at least 1000 pounds in the compressive strength of the concrete.

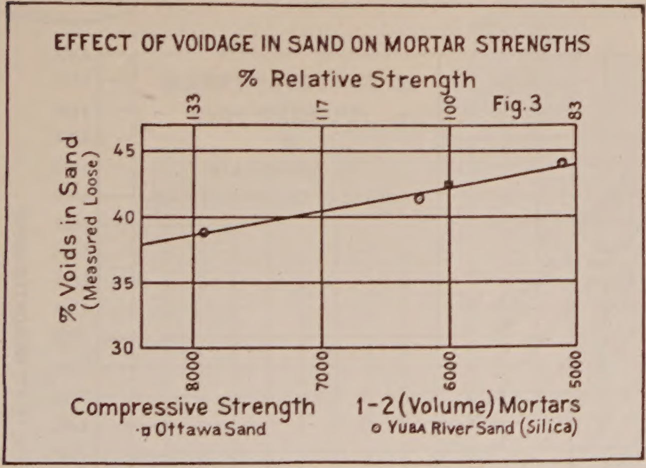

Figure 3

In Table Number 3, the probable strength of concrete using six sacks of cement to the cubic yard is shown with varying voidages in rock and sand. The sand used in this case is of a quality equal to that used for the tests, results of which are shown in Figure Number 3.

TABLE 3.
PROBABLE STRENGTH OF CONCRETE
Yield—1 cubic yard concrete for 6 sacks cement.
1-inch Slump—Uniform workability.
Materials uniform in quality except for variations in grading.

	Voids %		Approx.
Mix	Sand	Rock	Comp. Strength
1-2.2-4	45	45	2805
1-1.7-4	45	35	4182
1-1.63-3.77	35	35	4875

Poorly graded material used in Concrete Number 1 gives an estimated strength of 2800 pounds per square inch as compared with 4800 pounds per square inch with well graded aggregate used in Concrete Number 3, the amount of cement per cubic yard remaining constant. These figures may seem startling, but from our observation and experience in the laboratory, they are in reality conservative.

In some sections it was found that the larger sand particles were not quite as perfect in quality as the smaller, and this was taken into consideration in assuming that Concretes Number 1, 2 and 3 in Figure 1 would be of equal strength. As a matter of fact, if the sand consisted of pure silica particles graded as shown in the various mixes, Concrete Number 3 would not only be much less expensive, as is shown, but it would also be appreciably stronger.

During the last year we have had the opportunity to compare concretes on two jobs constructed in the same locality at the same time and using the same cement. The sand and rock in both cases was of high quality as to soundness of particles, but in one case a high standard of grading was maintained with low voidages; on the other, excessively fine sand was used. The amount of cement used per cubic yard of concrete was the same on both jobs. The average compressive strengths with the well-graded material averaged nearly 5000 pounds and on the job with poorly graded material, about 2000 pounds. In all fairness, it is to be noted that a somewhat wetter consistency was used on the job with the fine material, but the slump was reported as less than 2 inches and the specimens did not appear to have been excessively wet.

From the foregoing discussion it is very apparent that producers of sand and rock products can render great assistance in improving the quality of concrete and that for so doing, they can reasonably request some share of the saving effected, in proportion as it increases their cost of production. The service can be best rendered by assisting in establishing specification standards which will insure the use of sand and gravel with low voidages. It is necessary, if concrete is to be produced economically, that such materials be well and uniformly graded from fine to coarse at the time they are used. A high percentage of voids is always present when particles of the same size are loosely placed in a container.

Materials may be properly blended and mixed at the producer's plant but if segregation occurs before the material is placed in the mixer, some batches will consist of coarse particles with high voidage and other batches of finer particles with equally high voidage. The benefits derived from careful grading at the plant can be entirely nullified by segregation in handling. For this reason it is desirable that materials be furnished to the work in several sizes, each size well graded within its limits. Even then care is necessary in loading and unloading to prevent segregation of size. The design of plants in such a manner that materials can be furnished well mixed and well graded is essential, if the best concrete is to be secured for the least money.

Sand and Gravel Convention in Detroit in 1928

That the 1928 annual convention of the National Sand and Gravel Association shall be held in Detroit was determined at the meeting of the board of directors of the organization recently. January 4, 5 and 6 were selected as the best dates to avoid conflict with members' other engagements. Headquarters will be at the Book-Cadillac Hotel.

New Sand Test*

A New Rapid Field Method for Determining Moisture, Voids and Specific Gravity of Sand for Use in Concrete

By **CLOYD M. CHAPMAN**
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IF a definite and known quantity of water is to be used in each batch of concrete, then it is necessary to know at all times how much water is introduced into the batch with the sand. This is equally necessary whether the aggregate is measured, weighed or inundated. When measured or weighed, the amount of moisture must be determined. When inundated the amount of voids in the sand must be determined because these voids are filled with water. To know the amount of water needed, one must know the voids in the sand.

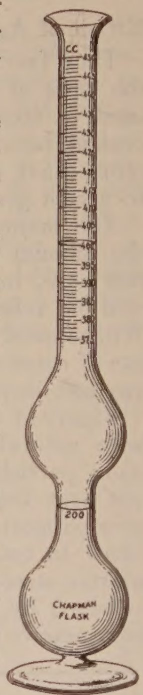
A new method for making field tests of voids or moisture has been devised which permits determinations of surface moisture or voids or apparent specific gravity of a fine aggregate to be made in a few minutes in the field with simple and inexpensive apparatus.

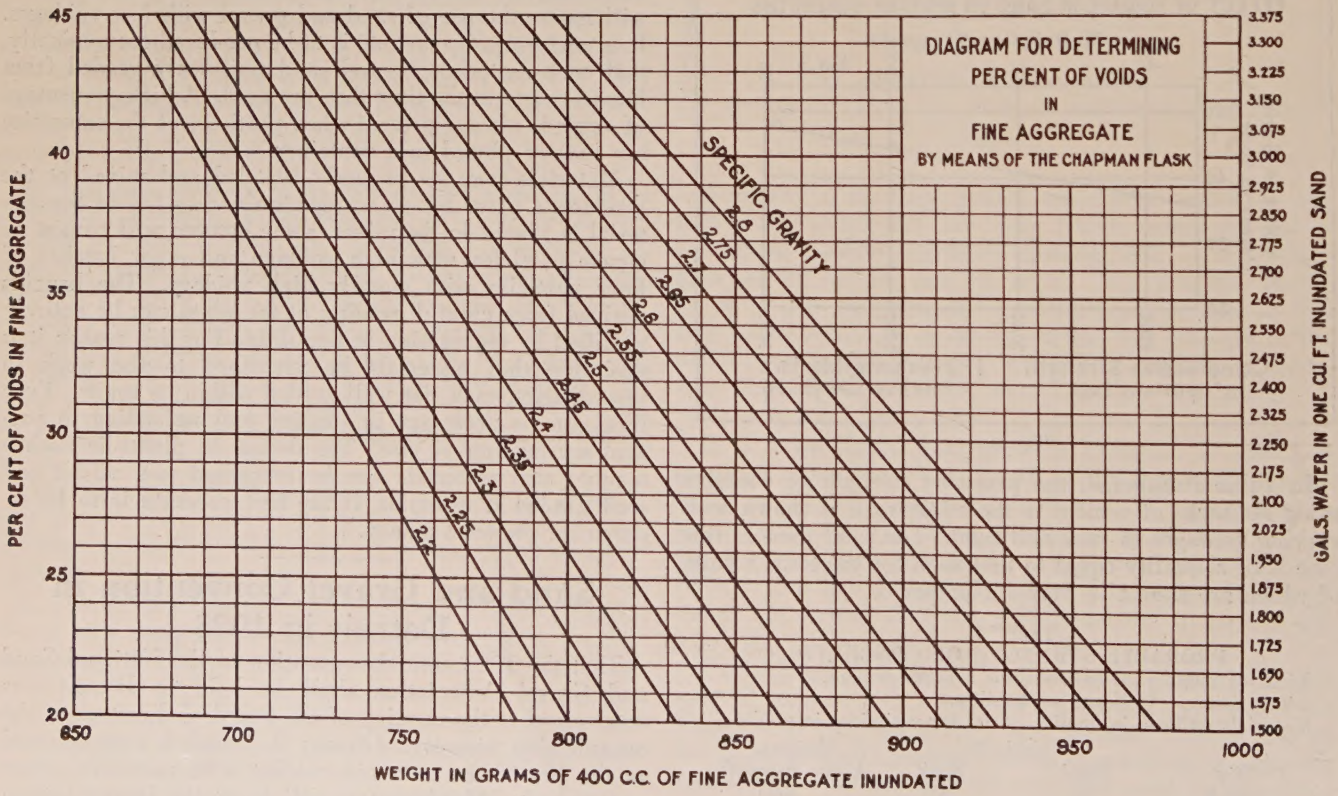
Test Equipment

The necessary equipment consists of scales, a special flask, such as is shown in the illustration and suitable diagrams for interpreting results. The diagram for use in determining per cent of voids in inundated fine aggregate is shown in Fig. 1. The method of operation is exceedingly simple. The lower bulb of the flask is filled about three-fourths full of water. The sand to be tested is then poured into the flask and if necessary more water is added until the level of both the sand and the water are at the 400 cc. mark on the upper neck of the flask. The flask and contents are then weighed, the weight of the flask is deducted, and by means of the chart the per cent of voids or the gallons of water per cubic foot of inundated sand is read directly from the chart.

If the specific gravity of the sand is to be determined, 500 grams of a surface dry sample are weighed out and introduced into the flask in which 200 cc. of water has previously been placed. The combined volume of the sand and water is read on the upper neck of the flask. By the use of a chart furnished with the flask the approximate apparent specific gravity is determined without any mathematical calculation.

When the moisture of a damp sand is to be determined the procedure is to fill the flask to the 200 cc. mark on the lower neck. Introduce 500 grams of the damp sand into the flask and read the combined volume of sand and water on the upper neck of the flask. By the use of a chart somewhat similar to that shown in Fig. 1, either the per cent of moisture in the sand or the gallons of water in 100 lbs. of the sand may be read directly.





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New Fire Test Is Successful

Fire Tests Made on Concrete Block Open New Market for Concrete Products in New York—Description of Test—Block Used Were Taken from Stock Piles of Six Manufacturers

A CONCRETE block fire test of more than usual severity and importance has just been successfully completed by the Columbia University Fire Testing Station on the product of six members of the Concrete Products Manufacturers Association of Brooklyn, to obtain the approval of the New York Tenement House Department and the N. Y. State Department of Labor for its use in fireproof walls and stairway enclosures. Written approval of the Tenement House Department for such use has already been granted as a result of the excellent showing made by the block, all of which were selected at random from manufacturers' stock piles.

Test Requirements

The test was made in accordance with the requirements of the rules and regulations of the Bureau of Buildings of the City of New York and the State Industrial Code, which requirements may be briefly summarized as follows:

The construction to be tested shall be subjected for three hours to the continous heat of a fire, rising in temperature to 1700 deg. Fahrenheit at the end of the first half hour, and maintained at an average temperature of 1700 deg. for the balance of the test. The temperatures shall be measured every three minutes by means of standard pyrometers at certain stipulated places on the wall. At the end of the fire test, a stream of water shall be directed against the construction, discharged through a 1⅛-inch nozzle, under 30 lbs. nozzle pressure, for 2½ minutes, the nozzle being held within 2 feet of the firing door and the hose stream being played over the entire fire surface of the construction under test. The test shall not be regarded as successful unless the following conditions are met: No fire or a considerable volume of smoke shall pass through the partition during the fire test; the partition must safely sustain the pressure of the hose stream; approval may be withheld if the construction should warp or bulge to an extent deemed dangerous by the Industrial Board.

Test Wall Construction

Two walls each 14 feet long, 9 feet high and 8 inches thick were erected in the partition test house, a cinder concrete structure reinforced with structural steel and reinforcing rods. One of these walls was built of hollow blocks and the other of solid blocks. All the block used were selected from stock of the manufacturers by Inspector Wm. D. Tyler of the N. Y. Tenement House Department, 25 each of the solid and hollow block being taken. One hollow and one solid block from the lot

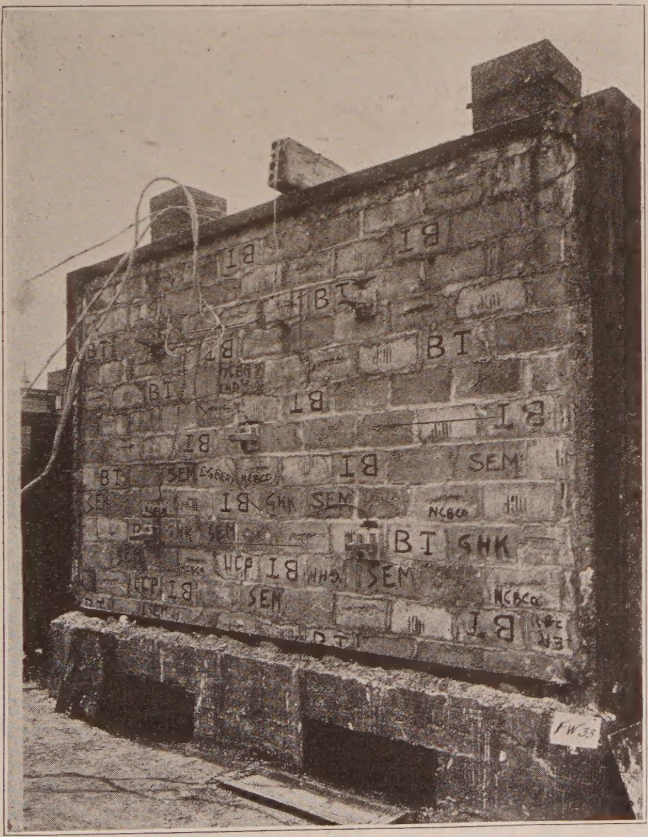

Figure 1

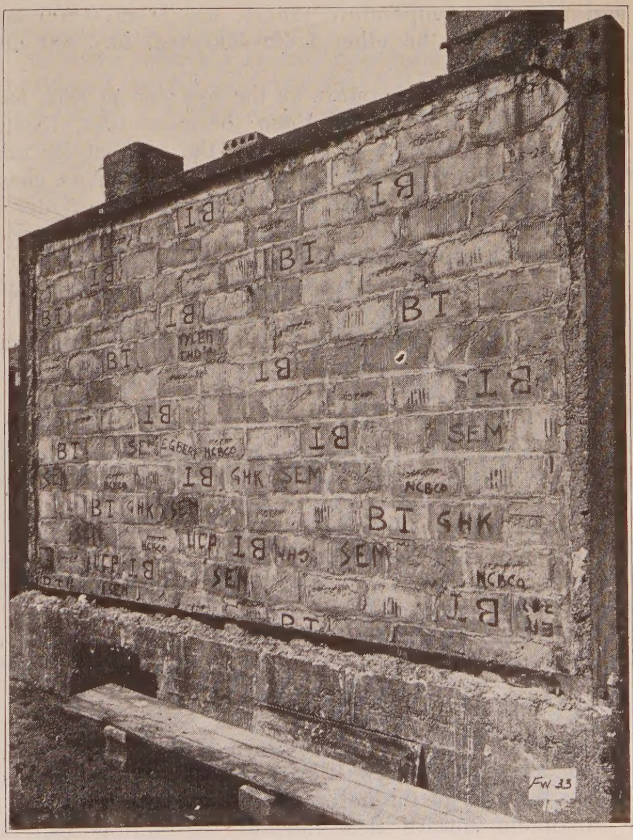

Figure 2

Figure 1 shows the wall before the test. The same wall after the test is shown in Figure 2. No change is apparent supplied by each manufacturer were sent to the Columbia University Testing Laboratory for standard compression tests.

The solid block were laid up in the easterly wall of the test house and the hollow block in the westerly wall. All blocks were laid in a portland cement mortar in the volumetric proportion of 1 part cement, 3 parts sand, and 1/20 part of hydrated lime. A sample of the mortar from each batch was moulded into a 2 by 4 inch cylinder to be tested later in compression. All joints were filled and averaged from ½ inch to ¾ inch in thickness and the workmanship represented an average grade only. Block were so laid that the distribution of block from the different plants was absolutely uniform throughout the wall. The appearance of one of the finished walls is shown in Fig. 1. Laying of walls was done March 22 and 23, and on April 16 both walls were given a plaster coat ranging in thickness from ⅜ inch to ½ inch, the plaster, Kings "Windsor" being mixed in the proportions of 1 part plaster to 2 parts sand by volume.

Test Procedure

The test procedure, as given in the official report of Columbia University, was as follows:

"One third of a cord of kindling wood and a cord of cord wood was spread upon the firing grate 9 ft. by 15 ft. in area. This wood was saturated with 3 gallons of kerosene and ignited at a number of places. The frequency of firing thereafter was governed by the temperature recorded.

"All temperatures were measured by means of thermocouples and recorded by a Leeds and Northrup potentiometer indicator. Constantan and iron wire thermocouples were used and all leads to the indicator were substantially of the same length. The temperature indicator was of the portable type with automatic cold junction compensation and with two temperature ranges, one from 0-600 deg. Fahrenheit and the other from 500 deg. to 2000 deg. Fahrenheit.

"The furnace temperature on the fire side of each wall was measured by one of these thermocouples, located about 26 inches below the top of the wall at its mid-length. It extended about 8 inches into the furnace chamber. A third thermocouple inserted through the center of the roof to a point 10 inches below the ceiling recorded the furnace temperature at this point.

"The temperatures reached on the outer surface of each wall were measured by 5 thermocouples, one placed at the center of the wall and one at the center of each quarter section. These thermocouples were protected by 6 inch by ½ inch asbestos fire felt pads. * * *

"The deflection of the walls during the tests was measured at the center and quarter points by scaling the offsets to the wall from a fine wire stretched horizontally 48 inches above the bottom of the wall.

"Temperature readings were made every 3 minutes during the first half hour and thereafter every 5 minutes. Deflection readings were made every 5 minutes during the first half hour and thereafter every 10 minutes.

"The water application at the end of the fire test was made by the Fire Department of New York City. * * *"

Test Results

The highest average temperature attained on the outside of the solid block wall after 3 hours was 141 degrees and in the case of the hollow block wall 169 degrees.

Maximum inward deflection of the hollow wall at the center was 1.54 inches at the end of 3 hours, and after the fire was extinguished the wall recovered until the deflection was only 0.88 inch. The maximum deflection in the solid wall at the center was 1.24 inch and the subsequent recovery after the fire was extinguished was to 0.96 inch.

The report goes on to state that some difficulty was experienced at the start of the test in maintaining the full 1700 deg. temperature owing to the fact that the block walls were water soaked from previous rains but this was soon overcome and the desired temperatures attained. A slight crack developed in each wall as the deflection inward appeared. This crack, which became slightly more apparent as the wall deflection increased, practically disappeared as the wall recovered at the conclusion of the test, and at no time did either crack pass smoke or flame. The interior plaster remained intact up to the conclusion of the test, although somewhat cracked, but was largely washed off the wall by the hose stream. The appearance of the block after the fire had been extinguished is shown in Fig. 3, in which some of the plaster can still be seen adhering to the block at the ends of wall. That the surface of blocks was undamaged can be seen from the fact that Inspector Tyler's signature of identification can still be read. Figure 2 shows the appearance of the same wall as in Fig. 1, but taken after the fire. No change in the wall is apparent.

Block for the test were supplied by B. Taranto, Geo. H. Krier, Egbert, Inc., National Cement Block Co., United Cement Products Co., and Semloh Contracting Co. The compression tests on the solid blocks indicated strengths ranging from 1260 to 2587 lbs. per sq. in. and on the hollow blocks from 1540 to 1794 lbs. per sq. in. gross area. The New York City building code requires 750 lbs. per sq. in. gross area. The only blocks in which any spalling took place were the solid block containing a coarse aggregate which showed the highest strength in the compression test.

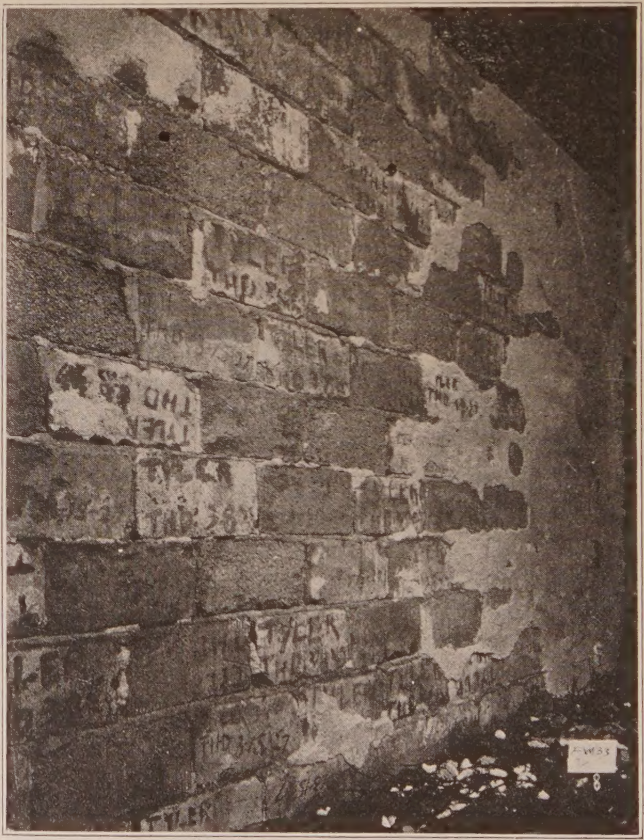

Figure 3. Most of the plaster on the interior wall was washed off by the hose stream, but the surface of the blocks was undamaged

The test was witnessed by Messrs. B. Glickman, Tenement House Department, N. Y. City; Edw. J. Pierce, Dept. of Labor, N. Y. State; J. Tjaden, Building Department, Borough of Brooklyn; S. Cohen, Building Department, Borough of Manhattan, J. Colemen, Building Department, Borough of Queens; L. D. McCormick, Building Department, Borough of Bronx, and representatives of the Fire Department, the Portland Cement Association and the various block manufacturers.

John E. Bleibtrey, Secretary of the Concrete Products Manufacturers Association of Brooklyn is entitled to the credit for arranging and staging the test in the face of considerable skepticism and opposition, in an effort to overcome a local situation where the tests made by the Underwriters Laboratories are not recognized by the state bodies for whom the test was conducted, and where the fire insurance rating bureaus have been reluctant to remove the penalties previously imposed on concrete block construction.

The test was conducted by Prof. A. H. Beyer, of Columbia University and Assistant Prof. W. J. Krefeld, of Columbia University.

Steel Required for Bond in Reinforced Concrete Beams

By R. T. REGESTER
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IN addition to the existing charts relating to numerous parts of reinforced concrete design, the accompanying diagram and table may be found useful in determining the perimeter of steel required for bond in beams of various sizes.

The following well known formulas (also given in the 1924 Joint Committee Standard Specifications) were used in obtaining the basis of the diagram.

Notation:
V = Total shear.
v = Shearing unit stress.
u = Bond stress per unit of area of surface of bar.
d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement.
j = ratio of lever arm of resisting couple to depth d.
Σo = Sum of perimeters of bars in one set.
b = width of rectangular beam or width of stem of T-beam.

$$v = \frac{V}{bjd}, \text{ or } V = vbjd \quad (1)$$

$$u = \frac{V}{\Sigma ojd}, \text{ or } V = u\Sigma ojd \quad (2)$$

By equating (1) and (2) a useful relation is obtained ("Principles of Reinforced Concrete Construction"—Turneaure and Maurer; p. 172) from which the diagram on the following page was prepared.

$$\Sigma o = \frac{vb}{u}$$

The table, supplementing the diagram, gives the total areas and perimeters of various numbers of round steel rods of different sizes. Another table for square rods can be easily prepared if desired.

As an example, assume a simple case of a rectangular beam with no web reinforcement. By previous design the following data has been obtained: b = 15 inches, v = 40 lb. per sq. in. from formula (1), and A_s, steel required for maximum moment = 0.75 sq. in. Also assume u = 120 lb. per sq. in. for deformed bars with hooked ends. Now referring to the value of b on the lower scale of the diagram, and following the arrow line it is seen that the required Σo = 5.0 inches.

Since the beam has no web reinforcing all bars will be considered unbent and running full length. Therefore, from the table a good arrangement of steel would be four ½-inch round rods.

The diagram and table are also applicable to slabs and T-beams with or without bent-up web rods.

Volume of Construction Continues Unequalled

The volume of construction operations now being carried on has never before been equalled. This is the indication drawn from statistics compiled by the Associated General Contractors of America showing the total volume for the first seven months of this year to be appreciably greater than the volume established during the corresponding period of 1926, when all previous records were broken.

Total Areas and Perimeters of Round Rods of Various Diameters

Number of Rods	⅜		½		⅝		¾		⅞		1	
	A	Σo	A	Σo	A	Σo	A	Σo	A	Σo	A	Σo
1	0.11	1.18	0.20	1.57	0.31	1.96	0.44	2.36	0.60	2.75	0.79	3.14
2	0.22	2.36	0.39	3.14	0.61	3.93	0.88	4.71	1.20	5.50	1.57	6.28
3	0.33	3.53	0.59	4.71	0.92	5.89	1.33	7.07	1.80	8.25	2.36	9.42
4	0.44	4.71	0.79	6.28	1.23	7.86	1.77	9.42	2.41	11.00	3.14	12.57
5	0.55	5.89	0.98	7.86	1.53	9.82	2.21	11.78	3.01	13.75	3.93	15.71
6	0.66	7.07	1.18	9.43	1.84	11.78	2.65	14.14	3.61	16.49	4.71	18.85
7	0.77	8.25	1.37	11.00	2.15	13.75	3.09	16.49	4.21	19.24	5.50	21.99
8	0.88	9.42	1.57	12.57	2.45	15.71	3.53	18.85	4.81	21.99	6.28	25.13
9	0.99	10.60	1.77	14.14	2.76	17.68	3.98	21.20	5.41	24.74	7.07	28.27
10	1.10	11.78	1.96	15.71	3.07	19.64	4.42	23.56	6.01	27.49	7.85	31.42

A = Total areas given in square inches.
Σo = Total perimeters given in inches.
Diameters of rods in inches.

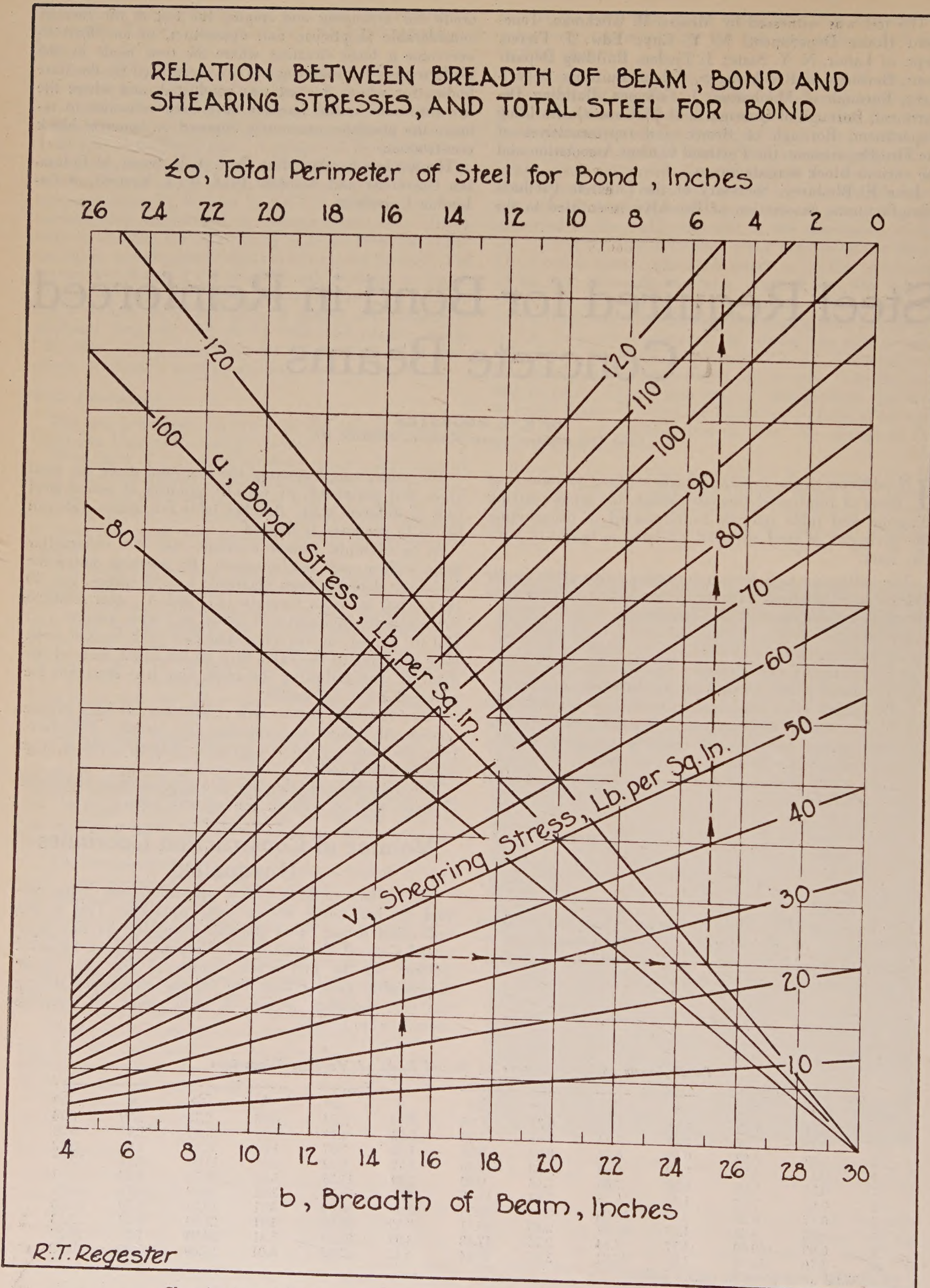


Chart for determining the perimeter of steel required for bond in beams of various sizes

A Contractor's Experience With Quality Controlled Concrete

Quality Controlled Concrete Used in Building Foundations and Tanks at New Plant of the Dewey Portland Cement Company at Davenport, Iowa—Methods Used—Strengths Secured—The Contractor's Experience with Controlled Concrete—Water Ratio Specification Found to be Practical

By W. A. PRIESTER
President, the Priester Construction Co., Davenport, Iowa

IN the construction of the concrete foundations and slurry tanks at the new plant of the Dewey Portland Cement Company near Davenport, Iowa, the general contractors, the Priester Construction Company of Davenport, were given an opportunity to make concrete according to the most modern methods of design and control.

The proportioning and mixing of all the concrete, except that placed in the tanks, was done by the use of an inundation plant. Aggregates were graded at intervals before the proportions were determined and the mixing was done with a careful control of the water content, based on the water-cement ratio law. The reason for accurate control of the quality of the concrete was to produce concrete of a predetermined strength, securing at the same time the required workability and the most economical combination of aggregates.

The work consisted of concrete foundations for machinery and buildings, the erection of circular slurry tanks and a water tank. There were about 13,000 cubic yards of concrete in the contract, 700 cubic yards of which were used in the construction of the tanks and 12,300 cubic yards in the foundations and slabs.

Specifications

The specifications under which the concrete was manufactured and placed were based on the water-cement ratio law. No mention was made of a specific mix of aggregates and cement such as 1:2:4 or 1:3:5. The actual proportions were to be determined by trial, so as to produce concrete having the strength required under the specifications, namely, 2000 pounds and 3000 pounds per square inch at the end of 28 days.

To attain a strength of 3000 pounds at 28 days, only 6 gallons of water were specified for each sack of cement. For the 2000 pound concrete, 7½ gallons of water were specified for each sack of cement. The water to be used included the water carried by the aggregate but did not include the water absorbed by the aggregate.

Slump tests were made at various intervals during the day's run, samples for these tests being taken just as the concrete left the mixer. The specifications called for the following maximum slumps for the various parts of the work:

	Inches
Mass concrete	3
Reinforced heavy foundations and walls	4
Reinforced beams and floors	5
Reinforced thin walls and columns	6

The concrete under the first two of these classes was to have a minimum compressive strength of 2000 pounds per square inch, while that of the last two was to be the 3000 pound concrete.

The proportion of the fine to the coarse aggregate was to be such as to produce smooth, plastic and easily workable concrete. The ratio of fine to coarse aggregate was to be within the limits of 1:1 and 1:2. Also the proportion of aggregate to cement was to be such as to insure a concrete plastic enough to fill all parts of the forms. The concrete batch was held in the mixer 1½ minutes.

Aggregate Proportions

The above requirements are, in a general way, the gist of the quality control specifications under which the concrete was to be made. They made it necessary for the contractor to design a concrete mix which would meet these requirements.

The aggregates conveniently available were carefully examined. It was decided to use a screened and washed bank sand for the fine aggregate and a screened limestone for the coarse aggregate. The sand was taken from a deposit near Rock Island, Ill., and the stone from a quarry near Buffalo, Iowa. Both materials were shipped to the job in gondolas.

At the beginning of the job sieve analyses were made of various samples from different cars of material to determine the fineness modulus of the fine and the coarse aggregates. During the progress of the work, the fineness modulus of both aggregates was determined at intervals, to check the average previously obtained. Throughout the job the fineness modulus of the sand averaged 3.40, while for the stone it averaged 5.20. The variation in fineness modulus for the sand was negligible. The stone was found to vary from 4.50 to 6.00.

The amount of water used in the mix was checked and carefully regulated at all times. When the concrete was first placed, 3 slump tests were made each hour but after average conditions were established slump tests were made only several times during the day's run. For the 3000 pound concrete the water-cement ratio was held at from 5 to 6 gallons per sack of cement. For the 2000 pound concrete from 7 to 7½ gallons were used.

The "trial method" was used to determine the proportions in which the aggregates and the cement were to be combined to furnish the concrete specified. The water content was held constant in all of the trial batches. Only the quantities of aggregate were varied until a mix was found that was satisfactory. Cylinders were made from these trial mixes. These were tested in compression at the end of 7 days. The probable strength at 28 days was computed by the formula: $S_{28} = S_7 + 30\sqrt{S_7}$.

The actual field mix for the 2000 pound concrete was 1 bag of cement: 3.38 cubic feet of sand: 4.62 cubic feet of stone. To secure the 3000 pound concrete, the quantities of aggregate were held constant while the amount of cement was increased and the amount of water decreased.

The following results were obtained from compression tests made on 6- by 12-inch cylinders at the end of 28 days, the loads being in pounds per square inch:

Type of Concrete	Low	High	Average	Number of Cylinders Tested
2000 lb.	2016	2460	2210	45
3000 lb.	2930	3680	3200	21

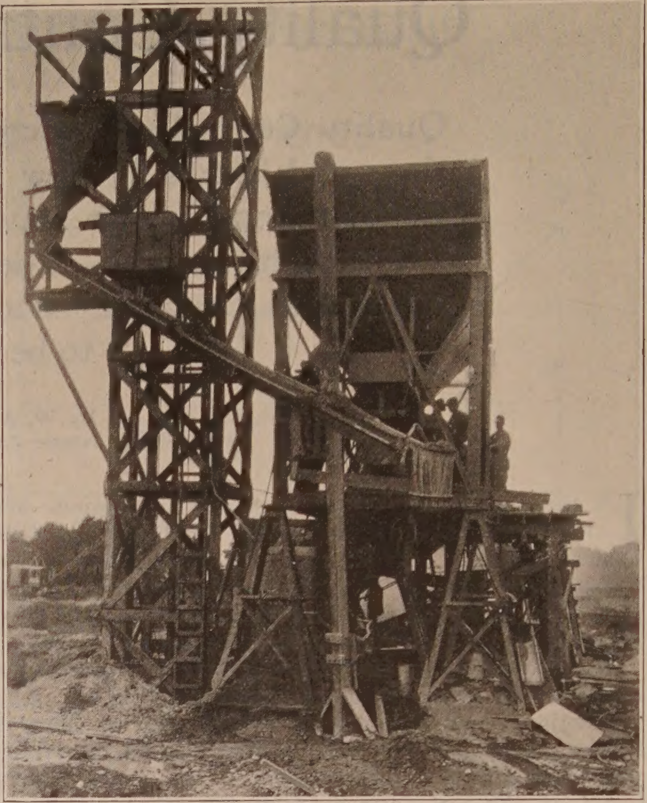
Construction Methods

The method adopted for placing the concrete on the general contract was unusual. This included all of the work except the slurry and water tanks, which were built separately.

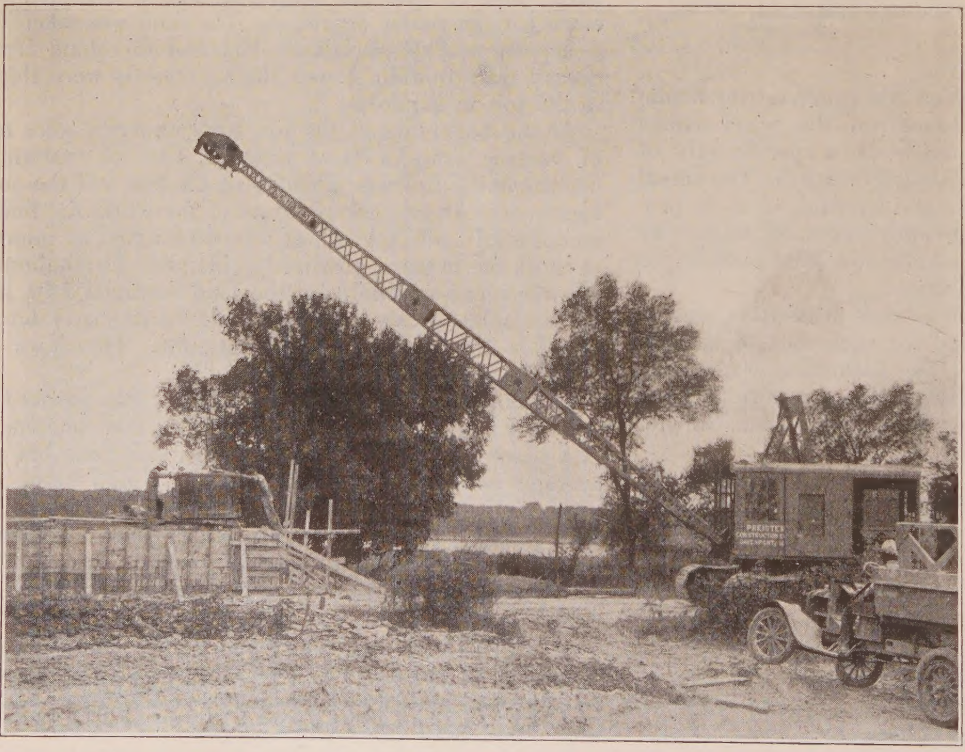
The central mixing plant equipment included a Blaw-Knox inundator (No. 115, 15 ton), a 14 cubic foot Ransome concrete mixer, a Clyde steam hoist and stiff leg derrick, a concrete tower about 125 feet high and a Lidgerwood steam hoist which was used in connection with the tower and to pull cement sacks up to the mixing platform.

The aggregates were unloaded either onto the stock piles or directly into the hoppers by the hoist and stiff leg derrick, from which they went through the measuring devices into the mixer.

Due to the fact that the concrete on this work had to be deposited at various places over an area of about 15 acres, a method of distributing it had to be devised that would cut down the time of placing and also would make a flexible unit that was inexpensive to move. The concrete tower had two hoppers, one about 25 feet above the ground, the other about 100 feet above the ground. The lower hopper had a short concrete chute and the upper hopper one that could be extended for a considerable distance from the tower. The concrete was chuted either from the top hopper to an auxiliary hopper at some distance from the tower or from the lower hopper directly into buckets which were carried on small trucks to the forms. Here a caterpillar traction crane lifted the bucket



This central plant mixed the concrete made for the job under water cement ratio specifications. The contractor selected his own proportions



Concrete was hauled in buckets by truck to the forms, where a caterpillar tractor crane lifted the bucket and placed the concrete from the truck and placed the concrete where desired.

The lower hopper was used for all concrete placed near the central mixing plant, while the upper hopper and the longer chutes took care of the concrete to be placed at a distance from the tower. This method also provided flexibility of operation because it permitted the placing of concrete at several different places during the same day.

Wood forms were used on practically all the work, the only exception being the circular tanks where metal forms were used. Considering the amount of concrete placed—approximately 13,000 cubic yards—very little patching was necessary. Most of the patching was done on a few wall sections which were placed during the first few days before perfect control was established.

The Slurry and Water Tanks

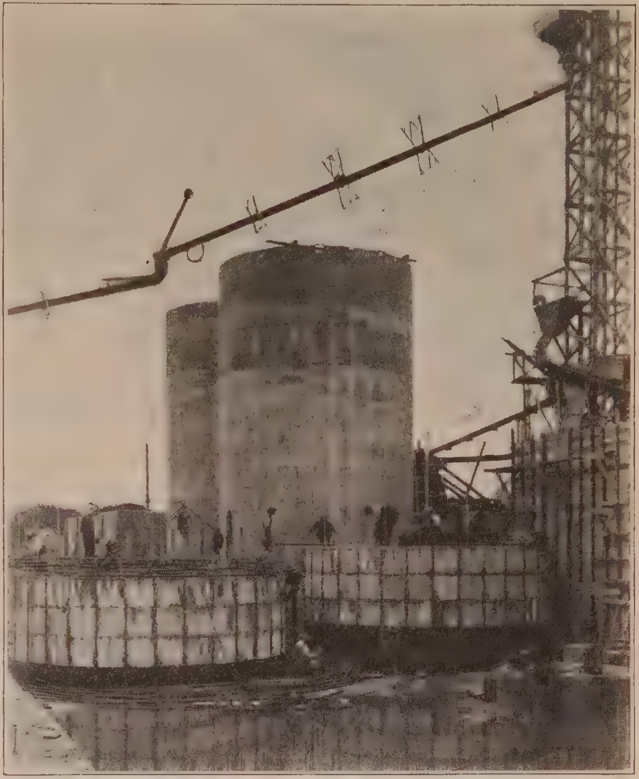
Part of the work done under this contract consisted of the building of 12 slurry tanks and a circular water tank. Because of the thin wall sections, the heavy reinforcing, and to the small amount of concrete placed daily, it was not possible to make use of the inundating batcher plant on this part of the work.

The slurry tanks were of two sizes, 9 of them being 40 feet high and 3 of them 24 feet high. The walls were 6 inches thick and the diameter of all the tanks was 20 feet. The water tank was approximately 85 feet high, 20 feet in diameter and had 12-inch walls. It was divided by a slab about 18 feet from the top to form two chambers, the lower and larger one being used for raw water and the upper one for purified water.

It was necessary to make the tanks watertight and it naturally was desirable to have the exterior surface free from voids and of smooth appearance. In the construction of the tanks, 8 pounds of hydrated lime were added to the mix. The water content in this work also was controlled as closely as possible. With the mix adopted, it was found that the concrete had sufficient plasticity to permit its placing in the heavily reinforced thin wall sections even though the water content was kept down to specifications. When the forms were removed the concrete showed a dense, even surface, free from voids. Even though the equipment used on this part of the work did not permit control of the water as accurately as at the central mixing plant, test cylinders showed that the 28-day strength of the concrete was considerably above the 3000 pounds required.

The water tower

The concrete for the tanks was mixed in a small mixer and hoisted to the forms in a small bucket. The metal forms used for each pour were removed after 24 hours and placed in position for the next pour.



The walls of the slurry tanks were only 6 inches thick and heavily reinforced. Yet a 6-gallon mix, supplying 3,000-pound concrete, was successfully placed

Conclusion

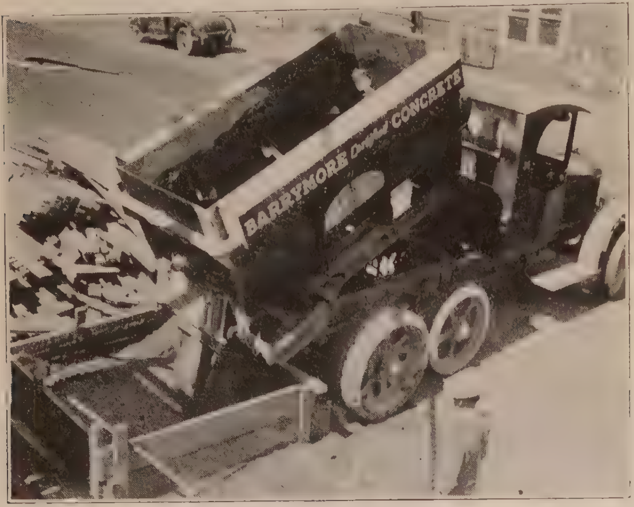
This was the organization's first job built under water-cement ratio specifications. Naturally, a little difficulty was experienced during the first few days in getting accurate control established, but after the first kinks were ironed out the job moved smoothly and efficiently. Water-cement ratio specifications are entirely practical from the contractor's point of view. They effect economies in the use of cement and aggregates and permit economical placing of the concrete. The comparatively dry mix used worked no hardship with the method of placing and distributing adopted. No appreciable segregation of aggregates was noticed after the control method had become thoroughly adjusted and running smoothly.

The Priester Construction Company of Davenport, Iowa, were the contractors for the work described. A. W. Priester is president and treasurer, O. F. Priester is vice president and J. C. Tunnicliff is secretary and general superintendent.

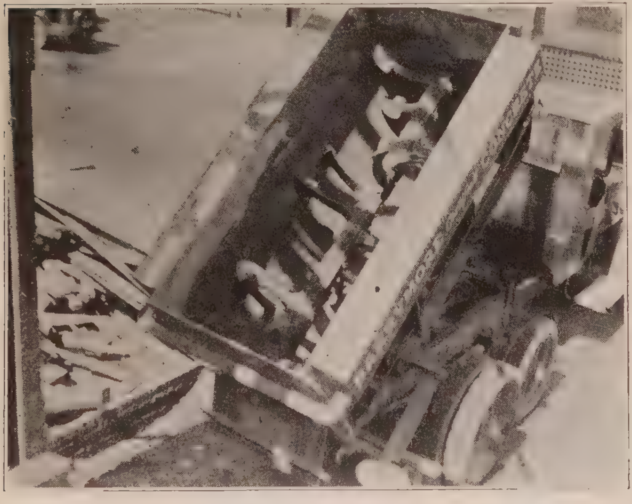
The engineers who designed and supervised the construction of the cement plant are the J. C. Buckbee Company of Chicago.

Truck Body Mixers Used to Deliver Concrete

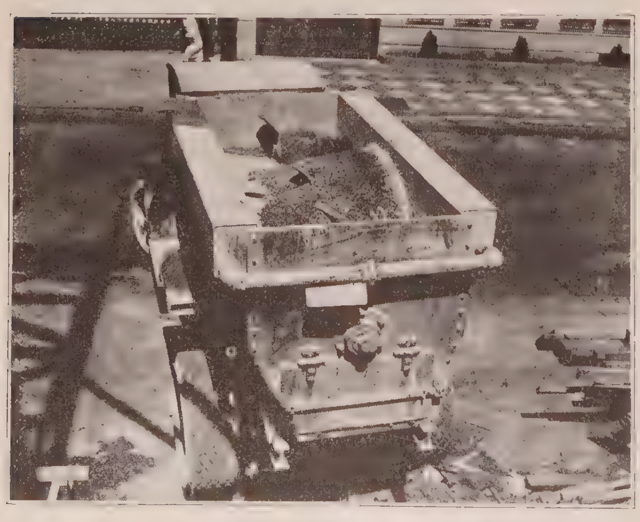
A recent development on the Pacific Coast is the delivery of ready-mixed concrete by means of motor trucks equipped with a concrete mixer, as shown in the accompanying illustrations. This method is now being used in California, Oregon and Washington.



Dumping the mixed concrete into the job hopper



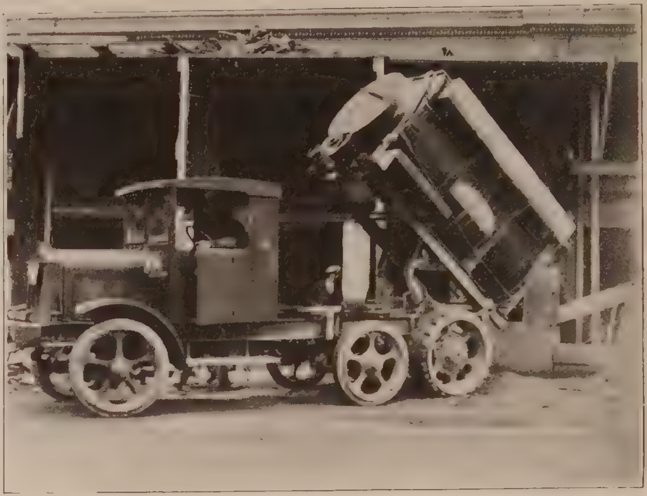
The paddles that mix the concrete in the truck body are revolved by the truck motor



The concrete batch is delivered to the job dry

The mixer consists of a specially designed truck body, carrying its own mixer and water tanks. The mixer itself is cylindrical in shape and is open at the top. It is driven under the proportioning bins where it receives the proper amounts of fine aggregate, coarse aggregate and cement for a 2½-yard batch. The materials are hauled to the job dry.

Water for the mix is carried in tanks attached to the mixer. A measuring gauge is installed so that the water content of the mix can be accurately controlled.



General view of the truck-mixer, showing method of discharging the batch

When the mixer reaches the job, the truck is stopped and the mixer started, using power from the truck motor. The materials are mixed dry while the mixer makes five revolutions, after which the water is added and the two-minute mix completed. The freshly mixed concrete is then dumped into a hopper from which it is conveyed to the forms and the truck returns to the proportioning bins for another batch.

Argentina to Have First Reinforced Concrete Highway

Washington, D. C.—Work will be started this year on the first reinforced concrete highway in Argentina. The first stretch will extend from Moron, just outside of Buenos Aires to Lujan, a town on the route to Rosario, a distance of 48 kilometers, Henry A. Bates, Assistant American Trade Commissioner at Buenos Aires, reports to the Department of Commerce. The estimated cost of the project, including installation of water works at Moron, is $3,782,500. The Lujan road is an experiment looking toward the construction of several tourist roads out of Buenos Aires and its development will be watched with interest by Argentine interests who are endeavoring to promote a widespread good roads movement.

Add New Qualifications for Public Work Bids

In order to place responsible contractors on public work, the Department of Highways and Public Works of the State of Ohio, has added the following and other paragraphs in the "Information to Bidders" form:

Hereafter, contractors submitting bids on state highway work will be required to attach to their bids financial statements and experience and equipment questionnaires, blanks to be furnished by the State Highway Department.

EDITORIALS

Water

WATER plays a most dramatic part in the making and placing of concrete. Without water, concrete could not be made and without water one of the most active agents of the deterioration of concrete would be removed.

It seems that the accurate control of water at the various stages in making and using concrete is very nearly the sum and substance of securing economical, strong and durable concrete. All down the line, water comes onto the stage and plays its leading role.

First, the amount of mixing water determines the strength of the concrete. Workability is a factor depending chiefly on the amount of water used. It influences the cost of placing the concrete. Adequate curing with water has a definite influence on strength and durability. And finally, the most durable concrete is that which excludes water to the highest degree. Strangely enough, the amount of water used in making the concrete influences the capacity of the hardened concrete for repelling water.

Concrete is one of the most durable of building materials. But even concrete is not exempt from slow, progressive deterioration. How great or how rapid that deterioration will be depends primarily upon its degree of porosity.

Those factors, then, that make for density in concrete — grading and proportioning of aggregates, amount of mixing water, workability and workmanship—determine, for better or worse, the durability of the resulting concrete.

Tests for Sand

IT has been pointed out that the present generally accepted method of testing sands to determine their suitability for concrete aggregate is not satisfactory and often even misleading.

In the light of recent developments in concrete practice, there are two weaknesses in the standard method of making tests by molding briquettes of a 1:3 mix and comparing their 7- and 28-day strengths with those of similar briquettes made with Standard Ottawa sand. Such tests do not take into account the water-cement ratio law nor the yield of the mix.

Take, for instance, two sands—one a coarse sand and the other a fine sand. The fine sand requires more mixing water than the coarse sand. This increases the water-cement ratio for the fine sand and naturally shows it up at a disadvantage.

A similar discrepancy is found when the yield of the two sands is considered. The fine sand mix will provide mortar for a greater number of briquettes than the coarse sand mix will, even though the proportions and quantities in the mixes are kept constant. The fine sand briquettes will, therefore, contain less cement than the coarse sand briquettes, still further lowering their strengths.

Such tests are only a partial indication of the value of the aggregate. They may cause the rejection of a sand that would make good concrete and require that another aggregate, often obtained at greater cost, be substituted. If a better test method, taking into consideration the factors of water-cement ratio and yield, were devised it would permit a more accurate determination of the concrete making qualities of a proposed aggregate.

Highway Specifications

AT least four state highway departments have adopted a clause in their specifications definitely limiting the amount of water to be used for each sack of cement in building concrete highways. A number of other states are using strength specifications requiring 2,500 to 3,000 pound concrete in their road work. This is practically equivalent to limiting the water content by specification.

Many highway and pavement jobs have been completed under water-cement ratio specifications. They have proved that such specifications are practical for highway work even though it seemed more difficult to apply such specifications on work where the mixer was not stationary. Also, it was feared that by limiting the water content, the pavement would be difficult to finish.

These difficulties were shown to be unimportant as water ratio control was tried out in practice. It was found that it was possible to control the water content even on a mixer that traveled forward as the pavement progressed. It was found that under highway construction methods the amount of water in the aggregates could be determined quickly and easily provided for. Experience has shown that finishing was improved when concrete of a uniform consistency was placed.

Fire Prevention Week

OCTOBER 9 to 15 is Fire Prevention Week. During that week newspapers and magazines throughout the country will feature the great losses resulting from fires that could be prevented.

It is not too early now to make plans for capitalizing the interest aroused during that week in fire-safe building. Fire Prevention Week gives the concrete products manufacturer and the concrete contractor an exceptionally good opportunity to drive home the fact that the materials they build with are fire-safe.

Here and There

Some Random Notes on Visits with Concretors in the Field

THE National Fraternal Society of the Deaf recently met in Denver, Colorado. Even here the subject of reinforced concrete buildings came up for discussion. One of the deaf delegates, commenting on the desirability of reinforced concrete buildings, said: "Where there are concrete floors, machinery isn't annoying to men without hearing, but wooden floors transmit such terrific vibrations that the deaf become perturbed and nervous."

He admitted that a boiler factory with wooden floors, while it might be all right for a man with normal hearing, would be unbearable to a deaf man. Thus another old-time theory has been exploded.

❦ ❦

NOT long ago we visited a fairly good sized city and started to look up the concrete products manufacturers in that town. We found two and both of them were real estate firms who made the block used in the houses they sold. There wasn't one concrete block manufacturer who sold his block to anybody who wanted it to say nothing of putting on an aggressive sales plan. The real estate people ran the plant when they wanted to build some houses to sell. When they didn't, the plants were idle.

❦ ❦

A PROMINENT structural engineer in Chicago recently said, "Architects and engineers throughout the country must wage a determined fight against certain outgrown restrictions imposed by building codes that impede progress and prohibit the use of new and improved construction methods and materials."

He might also have included contractors and products men, because they, also, are vitally interested in fair building codes.

❦ ❦

THE use of lightweight aggregates is growing rapidly. We called on a concrete block manufacturer the other day and he met us all smiles. The cause for his unseemly mirth at first was unexplained. But when he told us that he had just signed up for the lightweight aggregate rights in seven counties, we saw the reason.

❦ ❦

FIRE Prevention Week is not so far off. It is not too early to remind concretors of every persuasion and denomination that they can cash in on fire prevention week. Concrete can't burn. Sell that idea and get more business.

❦ ❦

AND here is a concrete products manufacturer that had a bright idea. When he was casting about for a suitable location for his proposed plant, he learned of an old abandoned duck farm that was for sale cheap. The location was ideal, the price right and the deal was made. He now uses the old duck houses for his curing rooms.

ANOTHER item often overlooked is the non-productive time that is put in by men and machines in the plant. This time is as much a part of the cost of the yearly production as is the cement used to make the blocks.

Sometimes, when the stock pile is pretty large and sales are slow, there is bound to be a lull in production. Then it is a fine thing for the boss to put the men on some good specialty. That is one way of cutting down non-productive time.

❦ ❦

EVERY concretor completed some job this year of which he is particularly proud. It is his prize job for some reason or another. Perhaps it was completed in record time, or some new methods of handling the materials were used. Or it may be that the structure is the most beautiful one that he has ever built.

Other concretors would like to know of this prize job. Why not tell them about it in the pages of this journal? Just send in the facts. Don't bother to write a finished story. If photographs are available, they will tell as much as a great many words.

❦ ❦

AND while we are on that subject, have you noticed the "Kink" page that has been running elsewhere in these pages for the last couple of months? You, too, surely have developed some "kink" on one or all of your jobs. If you will pass it on to your fellow concretors, they, too, will benefit by it. And you will benefit from the "kinks" sent in by the other fellow. A fair exchange is no robbery, you know.

❦ ❦

HOW many products manufacturers who own the property on which their plant is located figure rent as an item of expense? Of course, the property is theirs, but just the same it is worth so much if it were rented to some one else and it is only fair that the business occupying it should be charged that rental. This item is often overlooked entirely even if it does amount to a considerable sum each year.

❦ ❦

WHERE does all the cement manufactured go to? A Chicago investment company made an interesting map of the United States showing the percentage of the total cement production used by the various states in the Union. New York takes first place with 12.35 per cent. Illinois comes second with 8.7 per cent. Then come Pennsylvania and California. Nevada is at the foot of the scale with only 0.05 per cent.

❦ ❦

A PRODUCTS manufacturer recently told how he had worked up quite a business in selling roof and porch coping. He makes the units on a regular stripper machine. They are 16 inches long and can be sold at a price that underbids terra cotta.

Relation Between the Characteristics of Portland Cement *and* Deterioration of Concrete

A Discussion of Some of the Characteristics of Portland Cement and Concrete for the Purpose of Arriving at a Clearer Understanding of Why Some Concrete Remains Good and Why Some Disintegrates—Some Suggestions for Improving the Durability of Concrete

By JOHN R. BAYLIS
Filtration Engineer, Bureau of Engineering, City of Chicago, Ill.

Part III—Corrosion of Concrete

Having considered the characteristics of portland cement and studied the chemical reactions that take place when cement "sets," the discussion continues in this chapter with an examination of the reasons why some concrete deteriorates and some does not.

With these chapters as a background, it will be possible to make constructive suggestions for increasing the durability of concrete.

CORROSION is distinguished from disintegration in that it is a weakening of the concrete by the dissolving of certain compounds from the cement. As stated in Part I, the high calcium compounds of cement give up calcium hydroxide to approximately the saturation point of this compound. This means that the water within the voids of concrete that has not undergone any changes since being manufactured is strongly alkaline. In a recent article[3] the writer discussed somewhat in detail the causes for concrete corrosion. The present paper will give a partial digest of certain portions of the article, together with a more extended explanation of several points that seem to have been misunderstood by a few.

Solubility of the Cement Compounds

Portland cement does not form compounds insoluble in water corrosive to calcium carbonate. This includes the majority of our natural waters. There is usually an intermediate change of the calcium hydroxide derived from the cement compounds to calcium carbonate, and the problem of preventing corrosion is largely one of the solubility of this compound plus the protective action of the alumina and silica remaining after the calcium has been leached out. Rain water is fairly corrosive to calcium carbonate, and the surface and ground waters range in corrosiveness all the way from rain water up to waters like that of the Great Lakes, which is not corrosive. Concrete exposed to the Great Lakes water, or to other water of an equal chemical balance, should show practically no deterioration by the calcium being washed away, unless there is pressure sufficient to force water through the concrete.

Test Method

If equal weights of portland cement and water are sealed in a flask for several years, or long enough for all the particles to hydrate, the water will be found to be saturated with calcium hydroxide. The actual quantity of calcium hydroxide in parts per million of the solution may vary materially for commercial cements, due to the presence of sodium and potassium, but the solution is actually saturated with calcium hydroxide. If a large amount of distilled water is added to the flask, the mixture thoroughly agitated for a few hours, and the clear liquid is then withdrawn and replaced with more distilled water, the amount of sodium and potassium will be greatly diminished. When the amount of cement is approximately 10 per cent of the weight of water, there usually is not enough of the sodium and potassium remaining after the second quantity of water has been withdrawn to materially reduce the quantity of calcium hydroxide necessary to saturate the water.

Continuing the extraction of the calcium by repeatedly withdrawing most of the water at two weeks' intervals and replacing with distilled water, there is a gradual lessening of the amount of calcium hydroxide found in the solution. This is shown in Figure 4. Two weeks or longer should be selected for the time between tests, and the samples should be agitated frequently. In fact, it should run in a grinding and agitating machine for several hours after each replacement of the water so as to grind up any particles which have adhered. Very good results have been obtained by using a steel ball about three-fourths inch in diameter in Ehrlenmeyer pyrex flasks.

It is known that a stable equilibrium is not reached within two weeks, but changes for longer periods of standing are slow. The calcium hydroxide concentration of the solution, when below the saturation point, has in several tests increased about 10 per cent per year. The continued increase of alkali concentration in the solution upon standing is generally attributed to hydrolysis. Hydrolysis of a high calcium silicate means that the compound breaks down into calcium hydroxide and some lower compound of calcium and silica. It is chemical changes other than hydrolysis taking place in practically all the concrete that governs the rate of deterioration.

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[3] Corrosion of Concrete. Proc. Am. Soc. Civil Engineers, Vol. 52, 549-78, April, 1926.

With the exception of one fairly rapid drop in the curve shown in Figure 4 near the point where about 20 to 25 per cent of the calcium has been extracted, the changes in the direction of the curve are more or less gradual. It would be difficult to give a true interpretation of the curve and it is believed that this is not necessary for the present articles. There are yet many characteristics of cement not definitely understood, and it is our hope that the work under way by the Portland Cement Association at the national Bureau of Standards will eventually throw a little more light on some of the characteristics of cement.

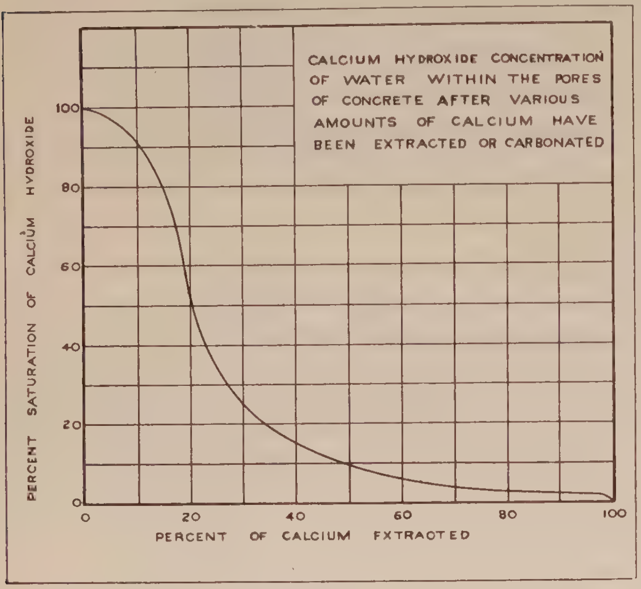


Figure 4

It is difficult to understand how a compound in which the reaction is as slow as that of the hydration of the high calcium silicates will unite with water to form a compound that later breaks down to calcium hydroxide and a silicate of lower calcium content. If there actually is hydrolysis of some of the cement compounds to the point of producing calcium hydroxide crystals, as there is some evidence to indicate, then, as has been stated, it must be caused from the production of a calcium silicate that forms only when there is considerable supersaturation of the calcium hydroxide. In other words, the production of the compound that hydrolyzes takes place under conditions that cannot exist after the cement sets. If this is the case, the rate of hydration should have considerable bearing on the amount of this compound actually formed. Then the question arises as to whether a great deal or only a little of the compound should be formed to give concrete its most durable qualities. The writer is of the opinion that any change in the crystallization of the cement compounds after the concrete has set should be regarded with suspicion, unless it is known that the change does not affect the strength of the concrete. There is one change in which calcium carbonate is formed by CO_2 gaining access to the concrete, that does not appear to weaken the concrete, but all changes do not behave in this way.

Changes That Cause Deterioration

The examination of concrete which has been submerged a number of years frequently reveals a few calcium hydroxide crystals in the voids, but the amount is almost insignificant. If the theoretical chemist is correct in that there is gradual hydrolysis of some of the cement compounds to the extent of supersaturating the water with calcium hydroxide the rate is so slow it is not of great importance in most of the concrete structures. We must look for other changes to account for most of the concrete deterioration. The writer has not found any concrete that has materially weakened but what causes other than hydrolysis are responsible; that is, the cause is so apparent there will be no suspicion of hydrolysis even materially aiding the deterioration. This point should be stressed, for most cement chemists seem to be of the opinion that, due to hydrolysis, nothing can be learned about the concrete by making a calcium hydroxide solubility test.

It is the purpose of the curve in Figure 4 to indicate or give an approximation of what changes have been taking place in the concrete, also to determine what reactions are likely to take place in the future should certain compounds come in contact with the concrete. If a sample of concrete gives up calcium hydroxide to the saturation point, then it is evident that under nearly all conditions there has been no great change in the cement compounds, but if it gives up calcium hydroxide to less than one-tenth the saturation point, which much of the old concrete will do, it is evident that none of the high calcium compounds are present and that at least 50 per cent of the calcium has been extracted, carbonated, or neutralized in some way. If certain compounds in water come in contact with the concrete, they may have a very detrimental effect when the high calcium compounds are still present, whereas if the calcium in these compounds has been carbonated there may be no chemical reaction. It is true the alkalinity test does not tell all we would like to know about the changes that have taken place, but it certainly is of aid in determining what should be done to protect the concrete. If the concrete is in such a location that it would have been impossible for the calcium to have been extracted to any extent, then it can be assumed that the change is due to the calcium being carbonated.

Hard Surface Layer

It is known that concrete is porous, and when it is exposed to rains or other water there is a tendency for the carbon dioxide in solution to unite with the calcium hydroxide that is diffusing from the interior to the surface. We are all familiar with the one-quarter to three-quarter inch of very hard concrete on the surface of old concrete, even on that that disintegrates, when exposed to rains. In many instances this hard layer has been formed at the partial expense of the concrete within the interior, for calcium is going into solution in the interior and being deposited near the surface as calcium carbonate. The precipitation of the calcium carbonate eventually stops up the pores.

The sketches in Figure 5 illustrate this point. The cement particles are assumed to be straight and the voids of uniform diameter. It, of course, is known that this is not the case and that the cement particles or fibers and the voids are quite irregular in shape and size. The sketches, however, serve to illustrate what is taking place near the surface of concrete. If the concrete is on the inside of a building and is protected from rains or other water, it merely carbonates from the surface inward. This is shown by the upper part of the sketch. It is likely that this causes an increase in strength in most instances, but it does not indicate that there will be an increase if the concrete is exposed to rains. The hard outside surface is still formed when exposed to rains but the concrete within the interior is usually weakened, especially that just inside of the hard outer surface. In many cases the concrete is being weakened to the extent of flaking off during freezing weather somewhat as shown in Figure 6. Concrete either must be protected from the weather or made so dense that there is no serious weakening of the concrete within the interior. Otherwise it will eventually fail as a great deal of it is now doing.

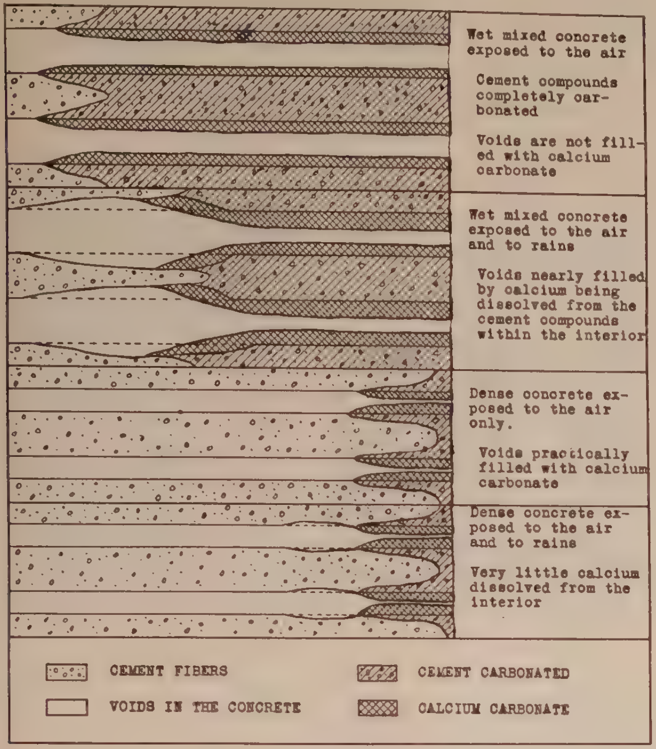

Wet mixed concrete exposed to the air
Cement compounds completely carbonated
Voids are not filled with calcium carbonate
Wet mixed concrete exposed to the air and to rains
Voids nearly filled by calcium being dissolved from the cement compounds within the interior
Dense concrete exposed to the air only.
Voids practically filled with calcium carbonate
Dense concrete exposed to the air and to rains
Very little calcium dissolved from the interior
CEMENT FIBERS
VOIDS IN THE CONCRETE
CEMENT CARBONATED
CALCIUM CARBONATE

Figure 5

This carbonization of the cement compound also takes place when the concrete is exposed to most natural waters, but where the water is not corrosive to calcium carbonate, the film in most instances gives almost complete protection to the concrete. Where the water is corrosive the film keeps dissolving away and more calcium hydroxide diffuses to the outside. There is a continuous change taking place by the calcium being washed away, which for good concrete, however, is very slow. The rate at which this change takes place is largely governed by the porosity of the concrete and the corrosiveness of the water. For most of the wet mixed concrete the dissolving of the calcium will be fast enough to seriously affect the strength of the concrete within 25 to 50 years.

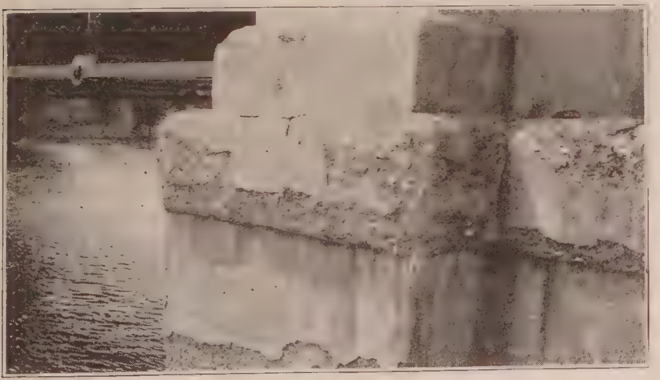


Figure 6

Effect of Mixing Water on Porosity

It is largely the spacing between the fibers or solid particles that determines the corrosive resisting power of concrete. This is best illustrated by comparing the volume of equal weights of cement mixed with variable quantities of water. The volume is a minimum when approximately 25 per cent by weight of water is used. This is the point of minimum voids and probably the point of maximum strength. It, of course, is evident that this is entirely too little water for proper working in actual practice. The addition of more water above the amount that gives the minimum volume increases the voids. Not by forming pockets of water, but by expanding the structural formation of the cement fibers. The addition of water to neat cement will increase the volume over the minimum to at least 50 per cent when the maximum amount of water it will retain is used.

Cement is composed of particles varying from almost sub-microscopic size to particles that will not pass a 100-mesh sieve. If the total mass is expanded 50 per cent, it will be much more than 50 for the finer particles that fill in between the larger ones. It has been found that the voids in neat cement mortar as determined by the writer's proposed void test varied from 29.5 per cent of the volume with 25 per cent by weight of mixing water to 49 per cent with 70 per cent of water. This represents considerable variation in the expansion of the cement particles, and an enormous variation in the rate at which water can pass through the concrete.

If diffusion rates, or water travel rates varied only in proportion to the voids the quantity of water used would make little difference, but an increase in the distance between particles increases the rates quite materially. Water passes through a coarse sand filter very rapidly, but if the sand was pulverized to the size of fine clay it would not pass at anything like its former rate. In fact, the coarse sand probably would pass more than one thousand times the amount of the pulverized sand. For small size openings the rate of water travel is not in proportion to the area of the opening. A tube one-hundredth mm. in area under a given head will not pass one-tenth as much water as one one-tenth mm. in area, and when the areas are only one-thousandth of a mm. or less, the proportional differences are even greater. The reason for this is a stagnated layer of water against all solid surfaces. This is an extremely thin layer and makes little difference in a large pipe, but if the diameter of the tube was only three or four times the thickness of the stagnated layer of water, then it would make a great difference.

When water is added to cement to the extent that there is actual separation of the solids and the water, the distance between particles is so great that the stagnated layers of water do not touch throughout the concrete to the extent of preventing water under a slight head from passing through it. If it were not for a decrease in the voids by the formation of calcium carbonate while or after setting, this wet mixed concrete would deteriorate rapidly when exposed to the weather. Notwithstanding this reduction in the voids it does disintegrate much more readily than when the optimum quantity of water is used.

Importance of Density

Density is wilfully sacrificed for economy of construction in modern concrete work. Under some conditions this may be justified, but any concrete exposed to water or to the weather on an important structure should be of the densest material possible, or it should be thoroughly protected by an impervious membrane.

Concrete wet enough to run in a chute with the angles of slope now generally used should never be exposed at the water's edge, especially if the water is corrosive to calcium carbonate and the climate is cold enough to cause freezing. In most instances such wet mixed concrete will begin to disintegrate within 20 years, and frequently in less than 10 years. The examination of disintegrating concrete on a number of structures under such conditions has almost invariably shown a large percentage of voids—not that it was honey-combed—but there was an expansion of the cement particles or fibers.

At the February, 1927, convention of the American Concrete Institute, Dr. P. H. Bates of the U. S. Bureau of Standards presented a paper on "Why Time Is a Factor in the Study and Use of Cement." Figures were given to show that an excess of mixing water has no appreciable effect on the strength of the concrete after 5 years when the excess water has a chance to escape within 2 or 3 hours after the concrete is poured. There is no fault to find with the fact that the strength does gradually increase under the particular conditions of exposure, but it leads many to believe that it is just as durable concrete as it would be if mixed with the proper amount of water. The contractor often prefers a wet mix, for wet mixed concrete is easier to handle and increases the volume of the concrete slightly so that a larger yardage of concrete is obtained with the same amount of materials. It also shapes itself in the forms more readily and there is not much danger of having honey-combed places should the workmen fail to work it properly after being poured.

The cement in wet mixed concrete would compare with the cement in which about 70 per cent by weight of mixing water is used. The actual volume of the cement filling the voids of the aggregate is increased about 25 per cent over what it would be if the right amount of water had been used for producing durable concrete. This produces several per cent increase in the bulk of the concrete. If wet mixed concrete is placed at the water's edge by the side of concrete which has the proper amount of water, there will likely be a different story to tell within 10 to 20 years.

Wet mixed concrete does gradually increase in strength in protected portions of the concrete, but this, in most cases, is due to carbonization of the calcium being released from the cement compounds. It is well known that the outside of concrete exposed to the air, but otherwise protected, is much harder than the interior.

Carbonization

The extent and depth to which concrete may be carbonated depends largely on its porosity. The concrete block on the right in Figure 7 was cut from an important structure about one year after it was poured, and was then stored in the laboratory for approximately another year. The one on the left was a block made for test purposes and was made just wet enough to be easily molded with very little tamping. The blocks were broken in two and a solution of phenolphthalein added to the fresh break. The part staining pink, which indicated the presence of high calcium compounds, was painted black for the purpose of photographing.

In the block on the right all the high calcium compounds have been carbonated for a distance of over one-half inch from the surface, whereas for the one on the left the carbon dioxide has not penetrated so deep. There is no doubt about this carbonization materially increasing the strength of the part carbonated, but it certainly has not increased the power of the concrete as a whole to resist exposed conditions. Some of this very concrete in the building began to disintegrate within two years after it was poured. Compressive stresses on the block after being stored for the time stated, while not made, would no doubt have shown it to be good concrete, yet it began to disintegrate in a very short time in certain exposed places where it was wet a large portion of the time. The chief cause was that the concrete was mixed so wet carbon dioxide had no difficulty in penetrating into the interior. This is causing it to increase in strength in most parts of the structure, but it is not increasing its durable qualities for certain exposed conditions.

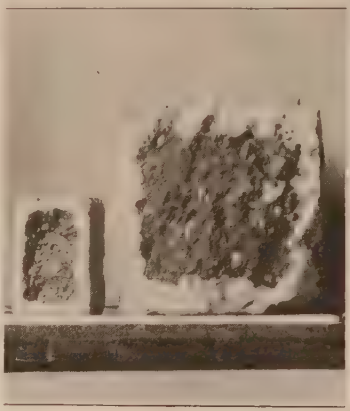


Figure 7

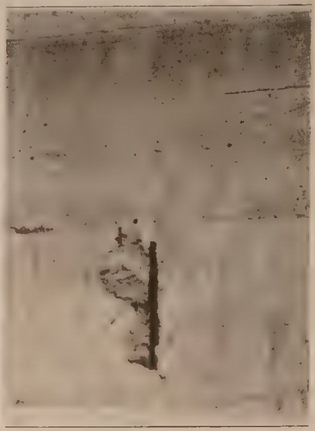


Figure 8

Removing Excess Water

The writer agrees with Dr. Bates that if the excess water can be removed and the concrete worked together to where it will not occupy a greater volume than it would if a lesser amount of water was used, that there will be no decrease in strength over what it would have been with the lesser quantity of water. There is only one way, however, in which the excess water can be removed to the extent of producing dense concrete, and that is to place the concrete in contact with some dry and porous material which will absorb the water. It is then necessary to work the concrete a little to make it shrink the required amount. The amount of calcium or other compounds carried away by the water is negligible insofar as it affects the strength of the concrete.

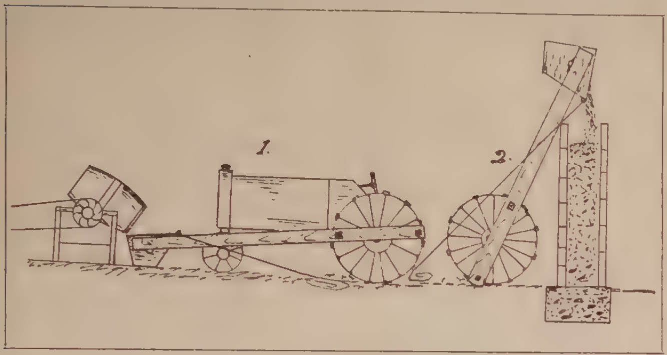
One of two things will happen to concrete exposed to the air. It will either carbonate to the extent of filling the pores with calcium carbonate, which will prevent further access of carbon dioxide to the high calcium compounds; or if the concrete is so porous that there is not enough calcium available which can be carbonated to fill the pores, the carbonization will gradually extend into the interior. The desired condition for exposed concrete is for the pores to be filled with calcium carbonate before all the high calcium compounds have been carbonated. It is nothing uncommon to find wet mixed concrete in which the carbon dioxide has penetrated several inches into the interior after a number of years. Where there is not enough available calcium for the carbonization to fill the pores in the concrete, the carbonated concrete has lost its last reserve power to resist corrosion. So long as it is protected it may remain good, but under exposed conditions it will gradually deteriorate in strength. There is also the possibility of the reinforcing steel rusting and causing the concrete to flake off, as shown in Figure 8, when the cement compounds are carbonated to the depth of the reinforcing.

Practical Kinks from the Job

A Home-Made Concrete Bucket Elevator

THE erection of large barns in the rural districts presents some unusual problems in which the equipment available must serve. One of these was erected at a time when the usual farm help was not plentiful.

The owner of the barn owned an 18-horsepower gasoline tractor and this was brought into use in a novel manner to do duty in elevating concrete to the top of the forms.



One side of the barn was next to a bank and this was to be constructed of concrete to a height of 10 feet. The filling of the lower forms for this was no problem but the upper 4 feet involved difficulties. Here the first tractor idea had to be worked out and the drawing shows how it was accomplished.

A box constructed like an ordinary coal pail and holding one charge from the barrel mixer at hand, was attached between two 2 x 8 timbers 14 feet long, by placing a long 1-inch bolt through the end of the timbers and through the box at a point so that gravity would hold the latter with the open end up. The two timbers were then cross-braced to each other. One of these was left straight and clamped to the inner side of one of the tractor drive wheels just above the hub while the other timber was sprung so as to fit against the outer side of the same drive wheel. Two bolts, fitted through holes of the timbers loosely so as to be easily removed, were used to clamp the timbers to the drive wheels.

By first maneuvering the tractor to determine the position of the mixer, then attaching the timbers and bucket, this simply designed elevator was ready for operation.

When the bucket was loaded the tractor was thrown in reverse gear and as the drive wheel slowly rolled backward by slipping the friction clutch, the bucket of concrete was elevated until it came to position over the forms. The dumping rope attached to the top edge of the bucket was then pulled until the contents were dumped in the forms.

Number 1 in the drawing shows the bucket being loaded from the mixer and No. 2 shows it after the tractor has been backed and the concrete being dumped.

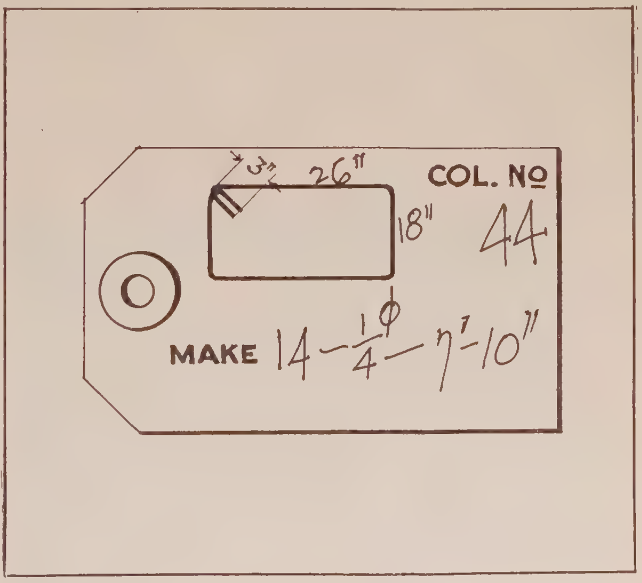
Tags Give Bending Details in Convenient Form

On a large reinforced concrete building job, particularly if the shape of the lot is irregular, quite a variety of hoops for reinforced concrete columns have to be made up by the steel laborers. Sometimes the bending details of these hoops are given on the reinforcing schedules, but often they are omitted, it being left to the foreman to work out the details from the plan size of the column. In any event many superintendents feel that the time of the foreman should be given, as far as possible, to keeping his gang or gangs moving rather than to poring over blueprints in an effort to obtain information which could be made available for him in more convenient and compact form.

With this thought in mind many concrete building superintendents make it a rule to give all the bending details for column hoops to the steel foreman in the form of linen tags on which are marked the details of the bends, the size of the metal, length of rod to be cut and the number of hoops required.

As the hoops for the average square or rectangular column differ only in the dimensions of the various sides, a rubber stamp can very easily be made up with a sketch of the hoop and a place for the column number, etc., so that the tag when stamped and filled in is similar to the illustration shown herewith.

These tags, if stamped with black ink and filled in with India ink, are surprisingly durable and give the steel foreman the information he wants in the most convenient and compact form. A file of these tags can be kept on a nail in the foreman's shanty and the tags for the different columns taken off and handed to the laborer at the bending bench in the order in which the column hoops are going to be wanted.



"Concrete" will pay from $2 to $5 for every kink accepted for this page. What is yours? Send it in.

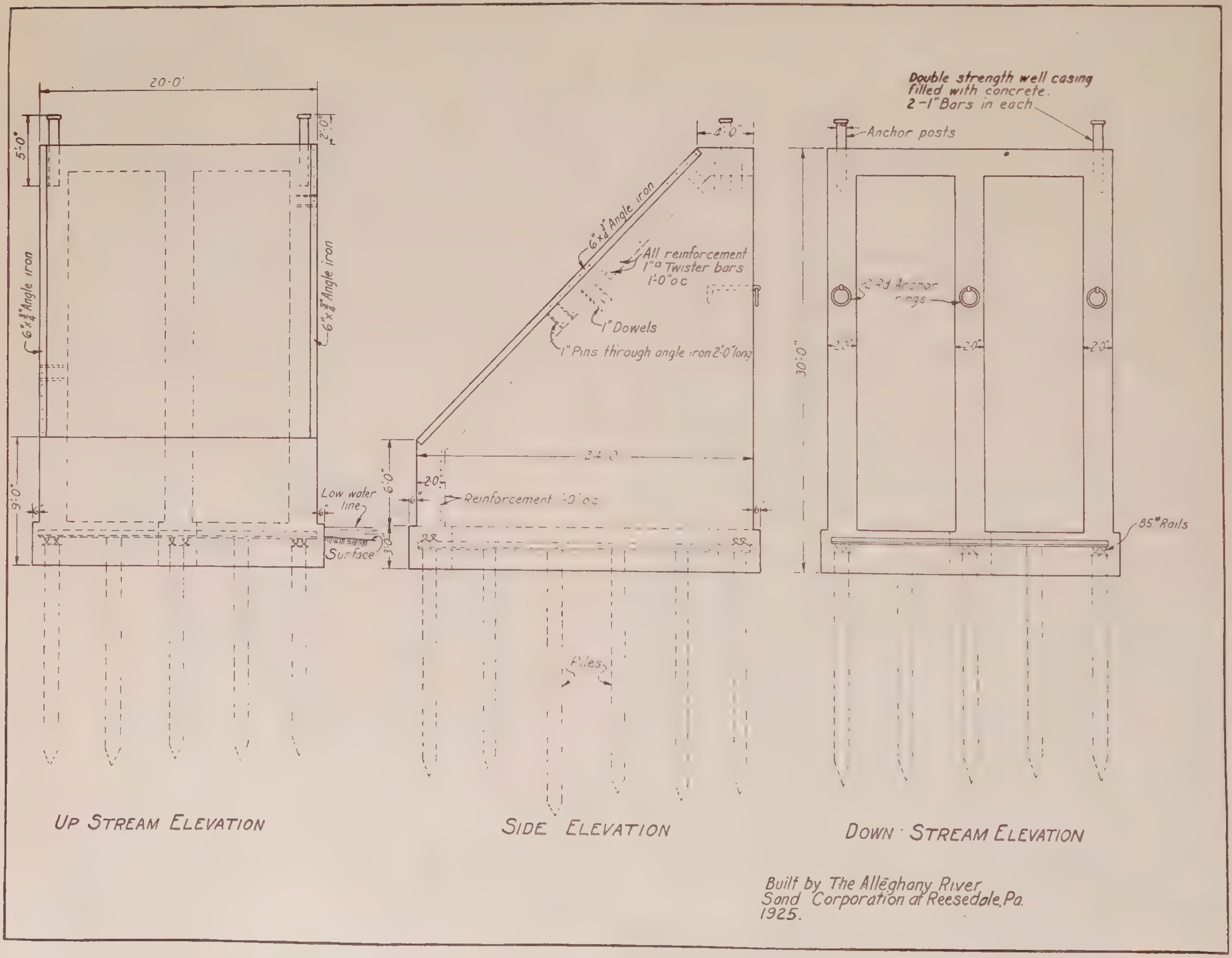
A Modern Type of Ice Breaker

In the summer of 1925, the Alleghany River Sand Corporation was confronted with the task of building two large ice breakers in the Alleghany River at Reesedale, Pennsylvania. These breakers were required to protect the equipment used in the river from large ice fields.

Using recognized practice for similar wooden structures as a guide, two reinforced concrete breakers were designed and constructed in October, 1925. Each breaker is supported by 22 white oak piles driven to refusal with a 2,000 pound hammer and tied together with 85 pound railroad rails capped with three feet of concrete. This foundation supports three parallel walls, each two feet thick with a two-way reinforcement of twisted 1-inch square bars, spaced 12 inches center to center. The two foot slab used on the upstream face is joined to these walls with two foot dowels of 1-inch bars and its edges are armored with 6x6x¾-inch angles. The breaker has a base of 21x25 feet and is 30 feet high. Each breaker required 165 cubic yards of 1:2:5 concrete and three tons of reinforcing steel.

B. R. Hebrank, Bolivar, Pa., was in charge of the work and P. J. Berford, Kitanning, Pa., was the contractor.

The ice breakers under construction



Working drawings of ice breakers built at Reesedale, Pa.

The A. B. C.'s of Good Concrete

Some of the Factors That Affect the Quality of Concrete—Why the Proportions Used and the Grading of the Aggregates Affect Workability, Yield and Cost—How to Select the Proportions That Will Make Good Concrete Economically

Part IV—Selecting the Mix

THE first steps in making good concrete, as discussed previously in this series of articles written for the practical, non-technical man, are the selection of suitable aggregates and combining them with the proper amount of water and cement, taking into account the water in the aggregates themselves.

But there are other factors that must be considered, especially when the dollars and cents viewpoint of concrete making and placing is taken into consideration. Among them are workability and yield. How to secure a mix that is workable and economical and yet will result in quality concrete will be discussed in this chapter.

IT has been shown in the previous chapter that the strength of concrete depended upon the amount of mixing water used, the best concrete being that which, *while it was plastic and workable,* contained the least amount of water.

It is also true that certain combinations of aggregates produce workable concrete with less mixing water than others. That means that the manner of combining the aggregates fixes the amount of mixing water needed and therefore does much to determine the quality of the concrete.

When you have selected the amount of water needed to secure concrete of the desired strength, the next problem is to find the most suitable combinations of aggregates that will give the necessary workability at the least expense. In considering this problem there are two things to be kept in mind: first, the need for a concrete plastic enough to be placed in the forms easily, and second, the dollars and cents value of getting the greatest amount of concrete possible from each bag of cement used, i. e., the yield.

Workability

Workability is a quality of concrete that is hard to define. Concrete that will go into the forms easily and will fill all parts of them without too much labor in puddling or spading and will, at the same time, show a concrete surface that is free from honeycombing or other defects, is workable. Workability depends upon:

1. Quantity of Mixing Water
2. Quantity of Cement
3. Size and Grading of Aggregates

A certain amount of fluidity will, of course, always be necessary. But this cannot be obtained simply by adding more water to the mix, if the strength of the concrete is not to be lowered. When more water is added, then it is also necessary to add more cement. That will increase the cost of the concrete considerably because cement is the most costly material that goes into concrete.

Concrete from this central mixing plant was hauled 4 miles. It was mixed very dry and was workable at the end of the haul

The best and most satisfactory way of getting workable concrete without increasing the amount of cement used beyond common practice is to select those aggregates that will give the greatest workability with the least amount of mixing water and to proportion them to the best advantage. How this can be done will be shown later in this chapter.

The slump test is a convenient measure of consistency and workability

Another method of increasing workability is to use admixtures of hydrated lime and other fine powders or pastes. Many contractors have found the use of admixtures of very great advantage, but it is a mistake to rely upon them entirely and neglect those other factors in making concrete that give workability. The subject of admixtures will be discussed in greater detail in a later chapter on that subject.

Effect on the Cost of Concrete

There are two principal factors that influence the cost of concrete. One of these is the cost of placing the concrete in the forms. Workability determines this cost. The other is the cost of the materials that go into the concrete. The mix determines this cost. The type of aggregates selected and the proportions in which they are combined influence both of these costs greatly.

A very dry mix can be used for concrete pavement work

The most economical concrete is not always the concrete that is made with the least amount of cement. It is true that the most important item in the cost of the materials is cement, but if little cement is used, little water can be used and the concrete may be so dry and harsh that the cost of placing it is far greater than the cost of more cement would be.

Another factor is the cost of the aggregates. With the ratio of the amounts of water and cement fixed, the use of a stiffer mix allows the use of a greater proportion of aggregates and therefore produces a greater volume of concrete for each sack of cement used. But here again too great an economy in this line will cause a greater expense in placing the concrete. The workability required is the governing factor.

Often, as most jobs go, it will be found practicable to use stiffer mixtures than has been the practice in the past, without increasing the cost of handling and placing. The problem is to find those proportions which will give the greatest workability at the lowest cost. Usually, with the customary range of prices, it will be found that the most economical mix will be one that is not too harsh for placing nor too high in fine aggregate for proper density.

If the coarse aggregate is increased beyond a certain point, it effects only a slight saving in cement while it runs up the cost of placing. On the other hand, if too much fine aggregate is used, more water is required and this, while it increases workability, raises the cement content far beyond the savings caused by easier placing. The "happy medium" is the most economical mix. A convenient measure of workability is the slump test described in the previous chapter of this series and published in the August issue.

An illustration of the economy of using the driest mixture consistent with the demands of the work will be found in the following table, showing the cement required to obtain greater workability. In all of these mixes 6 gallons of water were used for each sack of cement:

Slump in inches	Mix	Barrels of cement per cu. yd. of concrete	Gallons of water per sack of cement
½ to 1	1:2.1:3.8	1.5	6
2 to 3	1:1.8:3.5	1.7	6
6 to 8	1:1.5:2.9	2.0	6

The mix having a slump of from 6 to 8 inches (the most workable mix) required half a barrel more cement per cubic yard of concrete than the stiff mix at the top of the table.

Grading of Aggregates

The grading of aggregates is important for two reasons. It has an important effect on workability and on the amount of concrete secured for each bag of cement.

When the water-cement ratio is held constant, and a certain workability is wanted, a greater volume of coarse aggregates can be used when the larger particles predominate than when there are too many of the smaller particles. The ideal grading for aggregates, both from the point of view of workability and cost of materials, is when there are enough particles of all sizes present to fill the voids left by the next larger size. This grading should extend from the coarsest particles down to the finest.

It is important to combine the fine and coarse aggregates in the proper amounts. Too much coarse aggregate will give a mixture that is too harsh and that will result in honeycombing. A slight excess of fine material will give a smoother, more workable mix and will result in better surfaces. Too much fine material, on the other hand, will produce porous concrete. If the proportions of fine and coarse aggregates are kept within the limits shown in the following table, good concrete with workable consistencies will usually be obtained:

Max. size of coarse aggregate in inches	Ratio of coarse to fine aggregates	
	Maximum	Minimum
⅜	.8	.4
¾	1.5	.6
1 and over	2.0	1.0

How to Determine the Mix

There are two methods of designing concrete mixtures in which a definite amount of water is used for each sack of cement. One method, called the calculation method, uses the fineness modulus as a basis. This method was described in detail beginning on page 13 of the April, 1927, issue.

The other method is known as the "trial method." As the name implies, the mix is worked out right on the job by trying various combinations of aggregates. No computation is necessary. Both methods result in a workable mix in which the correct ratio of water to cement is used.

The selection of proportions by the trial method consists of the following operations:

1. From the information given in last month's chapter, determine the quantity of mixing water required to produce the necessary strength.
2. Make up a quantity of cement paste, measuring the amount of cement and water used.
3. Add fine and coarse aggregate until a mixture of the required workability is obtained. The better the

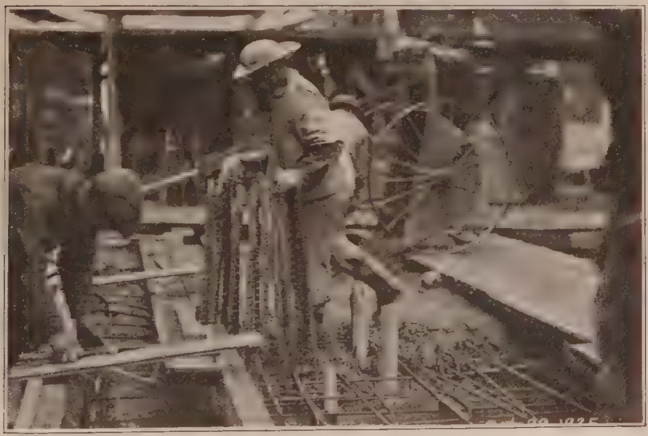
grading of the aggregate and the higher the proportion of coarse aggregate to fine, within the limits of workability, the greater will be the quantity of aggregates that can be added to the paste.

If only one fine and one coarse aggregate are available, the trial mixes can be most easily made right on the job, using full size batches. First of all, the amount of water in the aggregates themselves must be determined. This can be done as explained in Part II of this series, published in the July issue. Subtract this amount of water from the amount that is to be used, as described, and you are ready to make your trial batch.

For the first batch use some arbitrary mix as, for instance, a 1:2:4. A glance into the mixer will show whether the concrete is near enough to the consistency required to permit its use directly in the work. If it is not, some changes can be made before the batch is discharged from the mixer. If the mix is too stiff both water and cement in the proper ratio should be added. If it is too wet, either sand or coarse aggregate, can be added.

Study the first batch after it is discharged from the mixer. Its appearance and the ease with which is it puddled into the forms will suggest some changes in the proportions for the next batch. The most important question to settle is the relative amounts of fine and coarse materials and the total amount of aggregate to use with each bag of cement.

If a record of the quantities of materials used in charging the mixer is kept, it is a simple matter to compute the cost of the finished concrete for the various mixes tried. After making several trial batches, using varying proportions of fine and coarse aggregate, the most desirable mix can be selected, considering the cost of the concrete materials and workability. Of course, it is absolutely necessary in making trial batches to keep the ratio of water to cement constant.

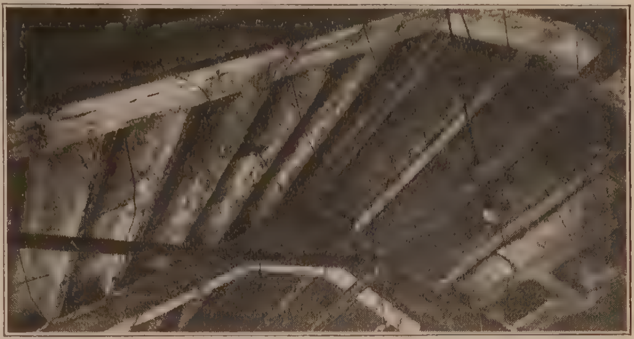


In heavily reinforced structural work, the concrete must be plastic enough to permit proper placing in the forms and around the reinforcement

When a number of aggregates are available, the same procedure can be followed with other aggregates or with combinations of aggregates from various sources. Sometimes is it well to work out the proportions with small trial batches in a field laboratory. But the method described will be found practical on 99 out of 100 jobs.

The next step for estimating purposes is to find out how much of each of the materials used in the mix selected will be needed for a cubic yard of concrete. This is a simple matter because the volume of concrete produced by any combination of materials is equal to the absolute volume of cement plus the absolute volume of the aggregate plus the volume of water. The absolute volume of a loose material is the actual total volume of the solid matter in all the particles. This can be computed from the weight per unit volume and the specific gravity by means of the following formula:

$$\text{Absolute volume} = \frac{\text{unit weight}}{\text{specific gravity} \times \text{unit weight of water}}$$



Honeycombing results when a mix that is not plastic is used. It is unsightly and weakens the concrete

This formula sounds complicated, but it really is not, as you will see from the following examples: Suppose that the mix you found to be the most satisfactory of all the trial batches consisted of 1 sack of cement (94 lbs.), 2.2 cubic feet of sand weighing 110 lbs. per cubic foot and 3.6 cubic feet of gravel weighing 100 lbs. per cubic foot and is to be mixed with a water-cement ratio of 7 gallons per sack of cement. The specific gravity of cement is usually about 3.1 and that of the more common aggregates about 2.65. Applying the formula in an attempt to find the volume of concrete produced by a one-bag batch of the proportion given in the example:

$$\text{Cement} = \frac{94}{3.1 \times 62.5} = .49 \text{ cu. ft.}$$

$$\text{Sand} = \frac{110 \times 2.2}{2.65 \times 62.5} = 1.46 \text{ cu. ft.}$$

$$\text{Gravel} = \frac{100 \times 3.6}{2.65 \times 62.5} = 2.18 \text{ cu. ft.}$$

$$\text{Volume of Water} = \frac{7.0}{7.5} = .93 \text{ cu. ft.}$$

Total Volume of Concrete Produced, 5.06 cu. ft.

Each 1-sack batch, therefore, produces 5.06 cu. ft. of concrete.

The cement required for 1 cu. yd. of concrete is therefore $\frac{27}{5.06} = 5.34$ sacks, or 1.33 barrels. Then since there are 2.2 cubic feet of sand used for each sack of cement, and there are 27 cu. ft. in each cubic yard, the sand required for each cubic yard of concrete is $\frac{5.34 \times 2.2}{27} = .43$ cu. yds. Similarly for gravel: $\frac{5.34 \times 3.6}{27} = .71$ cu. yds.

Thus the mix selected will require 1.33 barrels of cement, .43 cubic yards of sand and .71 cubic yards of gravel for each cubic yard of concrete in the job.

By using these methods it is possible to select a workable, economical mix that will produce concrete of a definite strength, provided of course, that the aggregates are clean and sound, that the water content is carefully controlled and that ordinary good practice is followed in mixing, placing and curing the concrete.

(The next chapter, to be published in the October issue, will discuss the effect of mixing time on the strength of concrete.)

Assumed Wind Pressure on Tall Reinforced Concrete Buildings

Wind Load Requirements in Building Codes—Variation in Requirements — Studies of Buildings Subjected to Storms — Actual Wind Stresses — Designing Against Wind Pressure

THE assumed wind pressure against which tall buildings should be designed is a subject that has become of much importance since the violent storms that occurred in September and October, 1926, in Florida and Cuba. The two storms were of about equal duration and intensity.

Before the time of those storms structural designers were inclined to consider that design against wind pressure was very nearly accomplished by the rigidity obtained when structural members designed for dead and live load were bolted or riveted together. This attitude was well expressed in the provisions of building codes of many large cities, in which the wind load requirements virtually were nullified by a provision immediately following, to the effect that the computed wind load stresses might be disregarded entirely if they did not exceed 50 per cent of the combined stresses due to dead load and live load. Where the wind stresses did exceed this limit the working stresses used by the designer were permitted to be increased by 50 per cent. Provisions of this kind are found in the building codes of New York City and Chicago. The codes of Milwaukee and St. Louis have similar nullifying clauses except that the limits are 30 per cent and 24 per cent, respectively, instead of 50 per cent.

Variations in Building Code Requirements

There is considerable variation in the building codes of leading cities regarding both the quantity of assumed wind pressure and the manner of its application. This is true even with cities in the same geographic location. For instance, note the following synopses of the requirements of three eastern and three mid-western cities.

The ***New York*** building code, in section 54, specifies a wind load of 30 lbs. per sq. ft., but wind load may be disregarded entirely unless the building is more than 150 feet high or unless the height is more than four times the least horizontal dimension. Furthermore, where wind load is required to be considered, the stress due to wind may be disregarded if it does not exceed 50 per cent of the combined live and dead load stress. If the wind stress does exceed 50 per cent of the live and dead load stress, the allowable working stresses may be increased by 50 per cent over those specified elsewhere in the code.

The ***Philadelphia*** code, in section 43, specifies a wind pressure of 30 lbs. per sq. ft. in exposed locations. In built-up areas it shall be figured at 25 lbs. per sq. ft. at the tenth story, 2½ pounds less at each succeeding lower story, and 2½ pounds additional on each succeeding higher story to a maximum of 35 pounds at the fourteenth story and above.

Miami Realty Board Building, Miami, Fla. This building, like others in Miami, was designed against a wind pressure of 20 lbs. a sq. ft., less an amount that varied with different structural members in accordance with a modifying clause in the building code. The steel frame, fireproofed with clay brick and clay tile, swayed so badly that panel walls were cracked and partitions shattered. The tile fireproofing in some places broke away from the columns, giving no assistance to the frame at the most critical points

The ***Baltimore*** code, in section 14, paragraph 3 (1920 edition,) specifies a wind pressure of 20 lbs. per sq. ft., but wind load may be disregarded entirely on masonry and concrete buildings whose height is not more than 100 feet nor more than four times the average width of the base.

The ***Chicago*** building code specifies 20 lbs. per sq. ft., but allows an increase in the unit working stress of 50 per cent over the stress specified in the code, although the cross-section of the structural member may not be less than would be required if wind forces were neglected.

The ***Milwaukee*** code, in section 123, specifies a wind load of 30 lbs. per sq. ft., but the allowable wind stress for combined wind load, live load and dead load may be increased by 30 per cent over the working stresses specified elsewhere in the code.

The ***St. Louis*** code, in section 114, specifies a wind load of 30 lbs. per sq. ft., but the allowable working stress for combined wind, live and dead loads may be increased by 24 per cent over the working stresses specified elsewhere in the code.

The Miami Code

Prior to the storm of September, 1926, the building code requirements of Miami, Florida, as regards design against wind pressure, were identical with the requirements in the Chicago code. During that storm the effect of the wind on three tall steel buildings compelled the revision of the opinions regarding wind load requirements. As pointed out in a number of published reports, three buildings of this type suffered seriously, one having suffered actual distortion of the structural frame to the extent that its demolition was ordered. The structural frames of the other two buildings did not suffer permanent distortion, but they swayed so badly during the 12-hour storm that much damage occurred to exterior panel walls and interior partitions and wainscoting. Investigators of these three buildings seem to agree that the one which suffered most seriously was neither well designed nor well built; but the same cannot be said of the other two. They were designed and built in accordance with what was considered good engineering and construction practice at the time of their erection.

Without making an actual stress analysis of each of the three damaged buildings in Miami it is impossible to determine for what amount of wind pressure they were actually designed. Different structural members in the same building would in fact be found to have been designed for different wind pressures. Many of the structural sections would be found to have no extra cross section because of the assumed wind pressure. This will be true in all sections where the wind load stresses figure less than 50 per cent of the combined dead and live load stresses.

From the experience gained at Miami it appears quite well established that the assumed wind pressure formerly specified by the building code of that city is inadequate to resist storms of great violence, especially where individual tall buildings are exposed for nearly their full height. An assumed pressure of 20 lbs. per sq. ft., if unmodified by a clause permitting wind pressure to be all but disregarded, *might* have provided a safe design.

Havana's Experiences

Considerable light is thrown on the subject from the fact that modern tall buildings in Havana, none of which suffered structural damage in the Cuban hurricane, are designed against assumed wind pressures of 25 and 30 lbs. a sq. ft. The building code of that city is not specific in its requirements regarding wind loads, so that designers follow what they consider safe practice, some designing against 25 lbs. a sq. ft. and others against 30 lbs.

However, another factor enters into the situation in a comparison between the two cities. In Havana all modern buildings have structural frames either of reinforced concrete or of structural steel encased in concrete, whereas the three damaged buildings in Miami had exterior panel walls of clay brick or clay tile, and columns were fireproofed with clay tile. This fireproofing gave but little assistance to the steel frame when the test came, since in many places the tile were completely broken away from the columns. The question then arises whether these three buildings, with their tile fireproofing, could have escaped damage even if they had been designed against 25 or 30 lbs. of assumed wind pressure. A second question is whether they would have escaped damage if they had been encased in concrete instead of tile units, even though they were designed against only 20 lbs. of wind pressure. Neither question can definitely be answered, but the probability is that concrete fireproofing would have increased the rigidity of the structural frame to the extent that no damage would have resulted.

It is expected that the revised building code of Miami will specify an assumed wind pressure of 25 lbs. a sq. ft. up to a height of 125 feet. Above this level the assumed pressure is to be increased by one pound to the story for the next five stories, the figure remaining at 30 lbs. from that point upward. If not nullified by clauses permitting wind stresses to be disregarded when not exceeding a certain amount, the proposed requirements will in all probability be sufficient for buildings having structural frames of reinforced concrete or of concrete-encased structural steel. Further experience may demonstrate whether or not these values are sufficient for steel buildings encased in tile units.

Actual Wind Stresses

The assumed wind pressure against which tall buildings should be designed may be investigated further from a study of the *actual* wind pressure caused by violent storms of the character of the Florida and Cuban hurricanes of last year. Information on this point is available from several independent sources. A. M. Messler, Chief Building Inspector of Miami, has been quoted as having estimated the pressure on one of the damaged office buildings in Miami at 68 lbs. a sq. ft. Engineers in the organization that designed and built another of the damaged structures have been quoted as having estimated the pressure on that building at 90 lbs. a sq. ft. A purely theoretical computation, based on the barometric pressure during the Florida storm, was made by A. N. Schoen, chief engineer of the Southeastern Underwriters' Association. He computed the pressure at 78 lbs. a sq. ft. The average of these three figures is very close to the figure obtained by Mr. Schoen in his theoretical computation. Consequently, until more definite information is at hand, one may assume that the pressure developed by the storm was not far from 80 lbs. a sq. ft.

Designers must not jump at the conclusion that a tall building, to be safe against similar storms, must be designed against an assumed pressure of 80 lbs. a sq. ft. When we are figuring against an ultimate wind pressure of 80 lbs. a sq. ft. we may at the same time utilize the strength up to the yield point of the structural material with which we are dealing. Remember also that the actual live load of a building is seldom, if ever, equal to the live load for which it was designed. This excess live load may be borrowed for use in resisting the ultimate wind pressure. For example, the former building code of Miami required offices to be designed for a live load of 50 lbs. a sq. ft. and the corridors for 80 lbs. During the storm the offices had an average live load of probably not more than 15 lbs. a sq. ft., while the corridors had none.

Providing for Safety Against Wind

Consequently in analyzing a structure with respect to its safety against a wind pressure of 80 lbs. a sq. ft. the designer might use the following method: First, compute the combined stress in an individual structural member due to the dead load and the *actual* live load, as nearly as the latter may be estimated. The difference between this stress and the stress in the member as its yield point then represents the stress available to resist wind pressure. Inasmuch as the effect of the wind pressure may be stated as so many pounds of stress for each additional pound of pressure, it will be a simple matter to determine the wind pressure that must be reached before the structural member is stressed up to the yield point. It will not be necessary to investigate all members of a structural frame in this manner. A few members in the most critical locations will be sufficient.

Engineering structures such as tall water towers and tall chimneys obtain little assistance from the shape of the structure. That is to say, the width is so small compared to the height that the structure acts more nearly like a single structural member. In such structures the resistance to over-turning should be carefully investigated, and in this computation the ultimate wind pressure should be used as a basis.

The actual performance of tall chimneys during the storms in Florida and Cuba furnish a good indication of what may be expected from well-built structures of this type. In Cuba some ten or twelve tall brick chimneys were damaged or destroyed, and two or three fell in Miami. Reinforced concrete chimneys, on the other hand, withstood both storms in an excellent manner.

A similar performance on the part of concrete chimneys was reported from southern Illinois, following the violent tornado of March 18, 1925. Six tall chimneys of this type located in the direct path of the storm suffered no damage. The good performance of reinforced concrete chimneys in severe tests of this nature can easily be understood from a study of a report on the Illinois storm, published in the Journal of the Western Society of Engineers, September, 1925. The report was prepared by a committee of structural engineers who investigated structures in the storm area, in behalf of the Society. An analysis of one of the concrete chimneys indicated that a wind pressure of 206 lbs. a sq. ft. would have been required to stress the material to the yield point. With so great a reserve strength to draw on, no trouble need be expected from a chimney of this material, although the designer must assure himself that the base of the chimney is sufficiently wide to prevent overturning.

Summer Course in Mix Control Held in Chicago

A short course in design and control of concrete mixtures that was held recently at the Portland Cement Association building in Chicago was divided into three groups, for architects, superintendents, structural engineers, material men; for building contractors, superintendents, industrial companies and public utility companies; and for city, county and state engineers, park commissioners, and railroad and sanitary district engineers. Each group met for three days, beginning June 14.

The course was conducted by J. W. Kelley and R. S. Phillips. F. R. McMillan gave an illustrated lecture on the fundamental aspects of the water-cement ratio.

Insulation Serves as Form in Architect's Building System

An idea in residential construction is being worked out in Kansas City, by Ernest O. Brostrom, architect, in which preplaced furring strips and insulation serve as forms and backing plaster. The studding and sheeting are reinforced with steel. Sills, ribbons and plates are poured with the studs and sheeting, producing a monolithic wall constructed upon a netting of reinforcement running perpendicularly and horizontally.

The interior of the wall will later be lathed and plastered with one of the standard materials now on the market. The exterior is to be finished with stucco.

Mr. Brostrom has named his system "Contee" construction.

Railroad Smokestack Repaired Successfully by Gunite Cement Gun

A 205-foot smokestack, property of the Chicago, Burlington & Quincy Railroad at Havelock, Nebraska, was repaired recently and resurfaced with Gunite. After knocking off the loose and disintegrated concrete, a Gunite jacket 2½ inches thick, of reinforced concrete was applied to the entire stack by Gunite cement gun.

How to Make
Concrete Sills and Lintels

Sills and Lintels of Concrete Should Be Made and Sold with Every Concrete Block Job—Types of Sills and Lintels — Manufacturing Methods — Costs and Sales Prices—Investment Required—Merchandising

IT is the most logical thing in the world to use precast concrete sills and lintels in a concrete block house. The products manufacturer who does not sell the sills and lintels that are used on the jobs for which he is supplying the block is neglecting a ready opportunity for additional profit. Many block manufacturers sell a considerable volume of these specialties on all types of building construction, realizing that it is often possible to get the contract for supplying the sills and lintels even if the building itself goes for another material.

Sills and lintels are easily made and they sell at prices that bring a bigger profit than concrete block. They can be made up during slack times in the block plant and put in storage for future sales.

Types of Sills and Lintels

Window sills vary in thickness from 4 to 8 inches, depending upon the height of the courses of block, tile or brick in the walls. Widths vary up to 24 inches. The length of the sill, of course, depends upon the width of the window and upon the design of the sill itself. Usually it is good practice to make them in lengths that conform to the masonry unit sizes. They can be placed more easily if they replace a definite number of full size or fractional block.

Sills are of two general types—lug sills and slip sills. The lug sill is one that is longer than the width of the window frame and on the ends of which a special lug is cast so as to permit the placing of masonry units against the sides of the window frame. A slip sill is one that is of the same length as the width of the window frame. Because the frame comes exactly to the edge of the sill, the walls can be laid up without the interference of a section of sill extending into the wall on either side of the window. Slip sills are usually inserted after the wall is laid up. Lug sills, of course, must be set at the time the wall is built.

Window sills should be designed so that they have a steep "wash" or slope to the weather. They should project at least 2 inches from the face of the wall. It is good practice to place a groove on the underside of the sill to form a "drip," as shown in the illustrations. This keeps the water from flowing onto the face of the masonry wall.

Under the usual conditions reinforcement is not required in window sills.

Lintels are usually made of the same height as the block courses. If an 8- by 8-inch block is used and a solid lintel is selected, it will be 8 by 8 inches in cross-section. If they are also made of a length equal to some multiple of the wall length of the block, they can be set as the wall goes up with very little trouble. Even though lintels of this size are larger and stronger than necessary, they effect economies because they save the labor otherwise required to fit odd sizes of block around lintels of special dimensions.

When hollow concrete masonry units are to be furred and lathed on the inside, one-piece lintels have been found to be satisfactory. Where a continuous air space is required for insulation or where interior plaster is to be applied directly to the masonry, the "split" or two-piece lintel is recommended. It is made in two pieces to provide an air space between the inner and outer sections.

Lintels spanning an opening of 3 feet or greater should be reinforced. For a 3- or 4-foot span two ½-inch reinforcing rods are needed. A 5-foot span requires three rods. For larger spans than this, heavier rods can be used. The reinforcing bars should be located about an inch above the bottom of the lintel to be most effective.

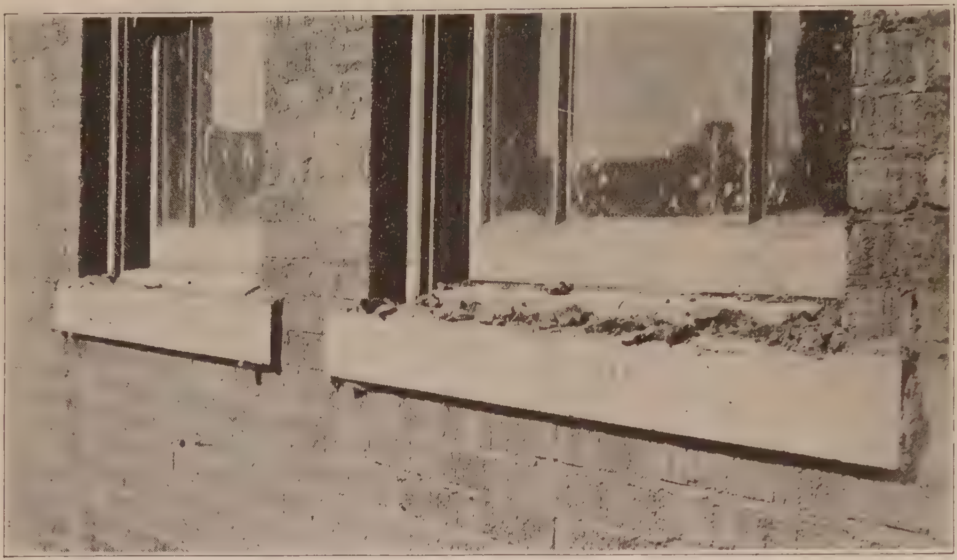
Manufacturing Methods

The methods used in making concrete sills and lintels resemble the methods used in manufacturing concrete trim stone. Indeed, some of the sills and lintels used represent a very high grade of craftsmanship. Naturally, the sills and lintels for some types of structures will be of a better quality and more expensive than those for other types of structures. All of them can and should be carefully made, the difference in quality and price being due to special facings or to special shapes. For the big bulk of the work, standard shapes and sizes are used and it is in these that the greatest volume of sales will be found. Manufacturing process for both sills and lintels is the same, except for placing the reinforcement.

A specially designed sill. Note that the height of the sill is equal to that of the masonry courses

There are two general methods for making concrete sills and lintels—the wet cast method and the dry tamp method. Both methods are being used successfully and both have features that recommend them. The method adopted by any manufacturer depends largely upon his personal preferences and on the plant facilities available.

When the dry tamp method is used, the materials should be mixed just wet enough to ball in the hand. Do not mix the concrete too dry. A mix that is wet enough to be "spongy" is used with the wet cast method. Too much water must not be used.



Two standard sills installed. Their height is equal to two courses of masonry and their length equal to a multiple of the wall length of the masonry units used. Precast sills are easily installed

Proportions

Some manufacturers use special facing mixtures on their sills and lintels and some do not. The advisability of using facings or not depends upon local requirements.

When facing mixtures are not used, a 1 to 5 mix has been found to be successful. The aggregate used should be carefully selected because it has an important effect on the appearance of the unit. The aggregate used should be well graded from coarse to fine and the largest particles should not exceed ½-inch in size.

When two mixes are used, the facing mixture should be proportioned 1 part of cement to 3 parts of the special aggregate selected to secure the surface finish and color desired. Do not use an excess of fine material in this mixture. Experience has shown that too fine an aggregate causes crazing.

For the body or back-up mix, proportions of 1 part cement, 2 parts of fine aggregate and 3 parts of coarse aggregate are used. The fine aggregate is graded from ¼-inch down and the coarse aggregate from ½-inch to ¼-inch.

For most of the sills and lintels made, the standard metal forms commercially available have been found to be the most satisfactory. A number of concrete block machine manufacturers also furnish these molds, which are adjustable for different sizes of units. These molds, of course, can be used only for making the standard shapes and sizes of sills and lintels. For special shapes, special molds must be used. These will be described in a later article on the manufacture of concrete trim stone.

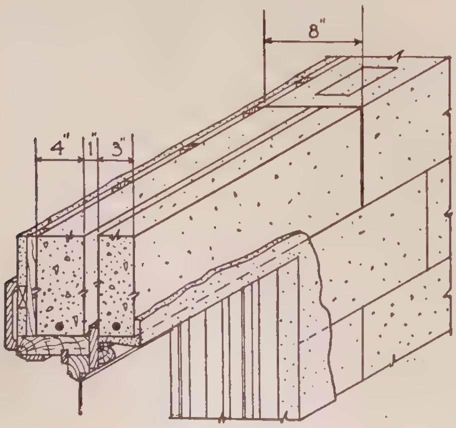
A great variety of surface finishes are possible. Sills and lintels can be made to harmonize with or duplicate the wall material in the building in which they are used. By the selection of special colors or combinations of colors in the facing aggregate, many pleasing surfaces can be obtained.

After the molds are removed, the film of mortar on the surface can be removed by washing the surface with a solution of 1 part of muriatic acid to 4 parts of water. This exposes the aggregate and helps to prevent crazing.

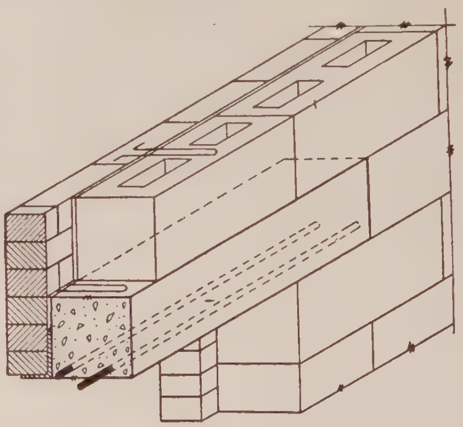
Merchandising

There are many reasons why precast concrete sills and lintels should be used. They are generally more convenient and economical than lintels and sills that are cast in place. Also the precast lintel and sill permits a greater range in color and surface treatment than cast in place units do.

Precast units do not delay the masons erecting the building. It is not necessary for them to wait until the concrete is poured and hardened before they can proceed with the wall. The precast units are quickly and easily



A two-piece lintel



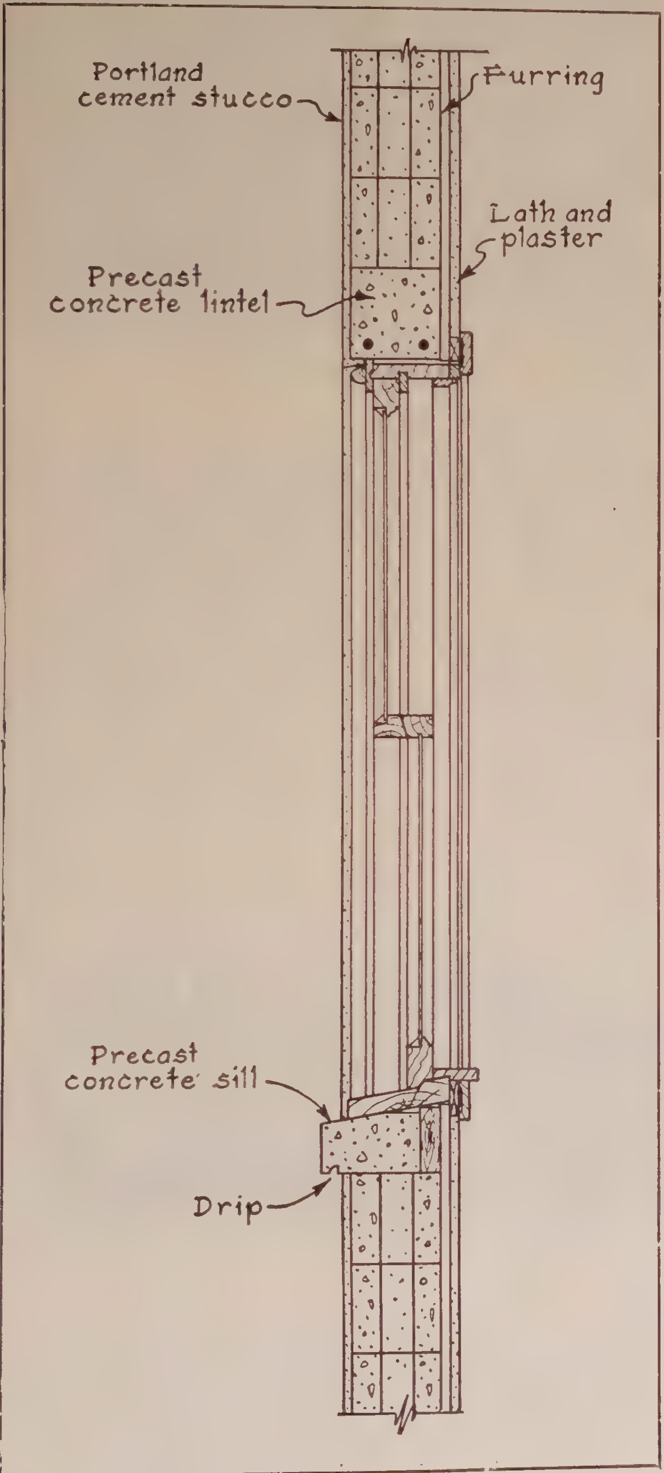
A one-piece lintel

put in place and the work of placing the wall units can proceed without interruption. Usually, also, the precast unit can be supplied at a lower cost than either cast in place sills and lintels or natural stone.

Leads for the sale of sills and lintels are obtained through leads for block jobs. When a salesman calls to sell concrete for a building or a foundation, he is right on the job to sell the lintels and sills as well. Often, even when he fails to sell the block, he still leaves with an order for the sills and lintels.

Investment Required

Very little investment is required to add sills and lintels to the products of a concrete block plant. An 8-inch form for lintels and two or three sill forms would be enough to get under way. Such equipment would cost only a little over $100.



Cross-sectional view showing method of installing sills and lintels

Products men who have been making sills and lintels find that one man can make about fifty feet of sills or lintels per day. Under average conditions, the manufacturing cost of a well made product will be about twenty-five cents per foot to forty cents per foot, depending on whether or not special facing is used.

These sills were made using a special facing aggregate

Sills sell at from fifty to sixty cents per foot for ordinary standard sizes. Special shapes and special surface treatments, of course, sell at correspondingly higher prices.

The block manufacturer who does not make concrete sills and lintels is missing a ready opportunity for additional profit

Coming Conventions

September 19th, 20th, 21st—Concrete Reinforcing Steel Institute, at the Aviation Country Club, Detroit, Michigan. Semi-annual meeting.

January 4th, 5th, 6th, 1928—National Sand and Gravel Association, at the Book-Cadillac Hotel, Detroit, Michigan. Annual convention and machinery exhibit.

January 9th to 13th, 1928—American Road Builders' Association. Cleveland, Ohio. Convention and Road Show.

February 28th, 29th, March 1st—American Concrete Institute, at Benjamin Franklin Hotel, Philadelphia, Pa. Twenty-fourth annual convention.

Huge Drainage Projects Use Precast and Monolithic Concrete Pipe

$14,000,000 Invested in Drainage Projects in Detroit's Metropolitan Area—Several Projects Under Way—Precast Concrete Pipe, Monolithic Concrete Pipe and Concrete-Lined Tunnels Placed—Construction Methods

THE city of Detroit has grown with such speed and with such a widespread expansion that it has overstepped its own county and taken into its metropolitan area counties lying to the north, northeast and northwest.

Like many other cities fortunate enough to have a flat territory to expand in, Detroit did not give much heed to modern public improvements until the pressing demand for municipal facilities grew to such proportions that the city was actually hindered in its expansion and attractiveness. Thus it is that every type of public facility—telephone, gas, electricity, sewerage and water supply has been brought face to face with a huge expansion program.

Of these facilities none has been more pressing than the need for sewerage and storm water systems serving not only Detroit and its home county of Wayne, but also the adjoining counties of Oakland and Macomb where much of the residential expansion has taken place. Some interesting concrete construction problems were met and solved in undertaking these public improvements.

In Oakland county the end of 1926 saw the completion of a large percentage of the great program begun in 1925. Due to the changes which have come about of recent years, the system being built has some remarkable features of construction and plan which will probably be followed liberally in other parts of the country now attacking similar difficulties.

Drainage systems heretofore have followed the simple scheme of building the drain from point of start to the nearest outlet by the most direct route. In the Detroit area this scheme has been curtailed by the fact that in 1926 the state passed a stream pollution law which compels all communities to stop polluting streams and lakes by emptying industrial and domestic wastes into them. The result of this law is that practically every municipality in the state is now engaged in planning sewage treatment plants and sewerage systems leading to these plants. The same problem had to be met in Oakland county with the result that the drain is not a simple point to point system but a system designed to carry from many of the county cities all the storm water and wastes to a central sewerage treatment plant to be built shortly.

The Oakland County Drain

The $14,000,000 system outlined for Oakland county will drain an area of some 22 square miles with a population today of more than 40,000 and estimated at many more thousands within a few years. The largest unit of this huge system is the Royal Oak drain which when completed will cost above $4,000,000. The Red Run drain, a similar project, will cost about $6,000,000 when completed.

The Royal Oak drain was more than 75 per cent completed at the end of 1926. As shown in the accompanying photographs this drain is divided into two sections, one section composed of monolithic concrete pipe and the other section of precast concrete pipe varying in size from 30 inches to 90 inches in diameter. So large are the largest sections of this pipe that an automobile can easily be driven through them and a tractor with a special rig was required to bring the units from storage yards to location along the trench. There are about 12 miles of monolithic pipe.

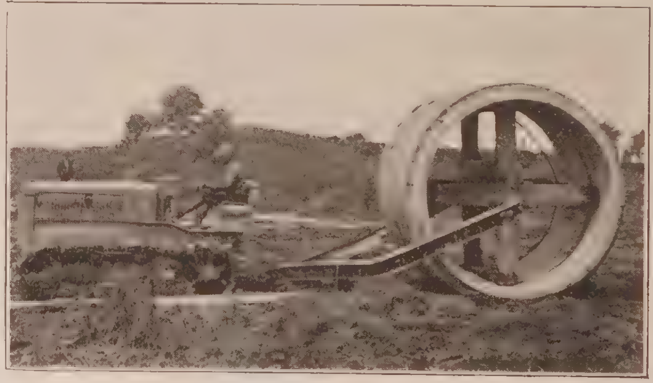
The monolithic section varies in cross-section from 6 feet 6 inches to 15 feet inside diameter including the tunnel work and open cut. There are 15 miles of precast pipe, the cost of which is about $1,500,000 exclusive of the labor of laying, digging the trench and other work connected with getting the pipe in place in the trench.

Placing the Large Pipe

Many interesting features were engineered in the work of building the section of the drain using precast pipe. Little difficulty was encountered in those parts of the job where pipe of small diameter were used. On the larger units, however, many difficulties had to be overcome.

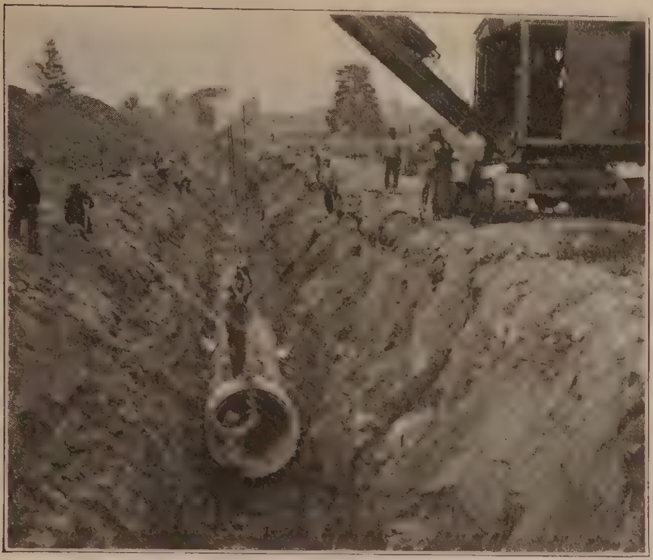
To get the sections from the stock yards a tractor with a special rig was used for pulling the pipe. Collapsible wooden cross members were placed inside the sections and nailed at right angles. Through the center of this cross an axle was run to connect at the outer ends with a steel divided tongue which was attached to the tractor. The units were thus rolled to position. All sizes were lined along the trench before the placing crews came along.

A tractor shovel with clamp attachment operated along the side of the trench and hoisted the sections into the trench. Inside the pipe already laid in place a windlass was placed and a rope attached to the section being placed. As the section was put into position the windlass rope was drawn tight drawing the section tight up against the one previously placed. Very close fitting joints were secured by this method.



A tractor was used to pull the pipe from stock to the trench

The precast pipe was manufactured according to the standard specifications of the Concrete Pipe Association. The larger units were reinforced and all sizes had a tongue and groove joint. Three firms manufactured the pipe used on the Royal Oak drain. The Independent Concrete Pipe Co. furnished pipe running in size from 48 inches to 90 inches in diameter. The Jackson Concrete Pipe Company of Jackson, Michigan, furnished pipe for one mile, ranging in size from 60 inches to 66 inches in diameter. The United Fuel and Supply Company of Detroit, Michigan, supplied pipe for two miles of the job, the pipe varying in size from 36 inches to 48 inches in diameter.



A steam shovel, operating along the side of the trench, was used for placing the pipe in position

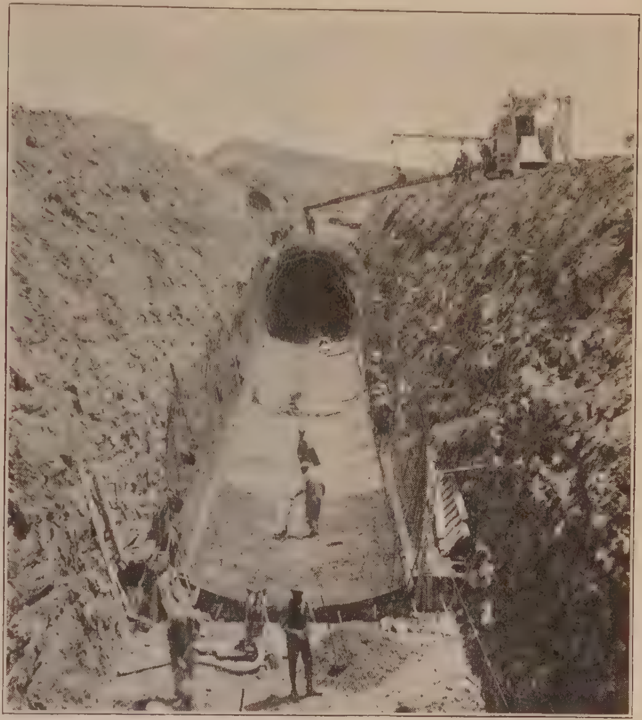
The job of laying the pipe section of the drain was contracted to three firms, all of Detroit. These firms were S. A. Healy, R. A. Mercier and R. D. Baker. The S. A. Healy Company also placed one and one fourth miles of four foot brick tunnel under boulevard and business property.

The Monolithic Section

The work of building the monolithic section of the drain was done by two of the Detroit firms—R. D. Baker and R. A. Mercier. A portable mixer was used to mix the concrete. The mixer ran alongside the trench and the concrete was chuted into position directly from the drum. The pipe was divided into two sections; a floor section and the upper. The floor section was almost flat, having just as much curve as the curve in the floor of the pipe. This part of the pipe was placed first, finished and cured before placing concrete in the upper part of the pipe. As shown in one of the illustrations, the reinforcing for the sides was put into position when the floor was placed. At the end of each section of the floor temporary forms were placed, later used to form joints.

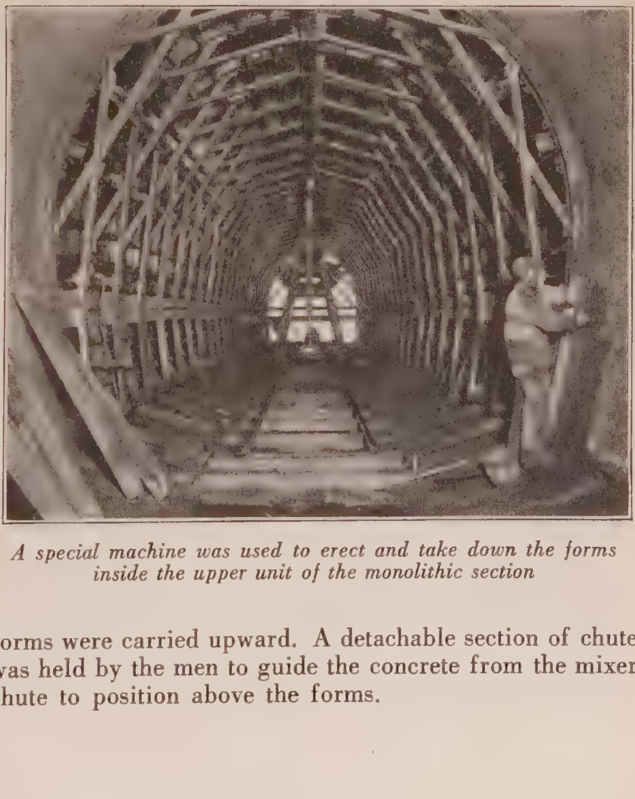
After the floor had been placed, collapsible inside forms were erected and outer forms, also sectional, were put into position. The inside forms were of steel and employed five sections for the largest size monolithic pipe. The sections were joined and bolted together by angle iron braces which ran from section to section. At the bottom these sections were braced apart by wooden forms laid upon the finished floor.

A special machine was used to assemble and take down these sections. The machine ran upon a track laid upon the wooden floor braces. It was "A" shaped and had four steel arms which fastened upon the section to be handled. By means of suitable ratchets and chain hoists mounted in the machine practically all the heavy labor of handling the sections was done away with.



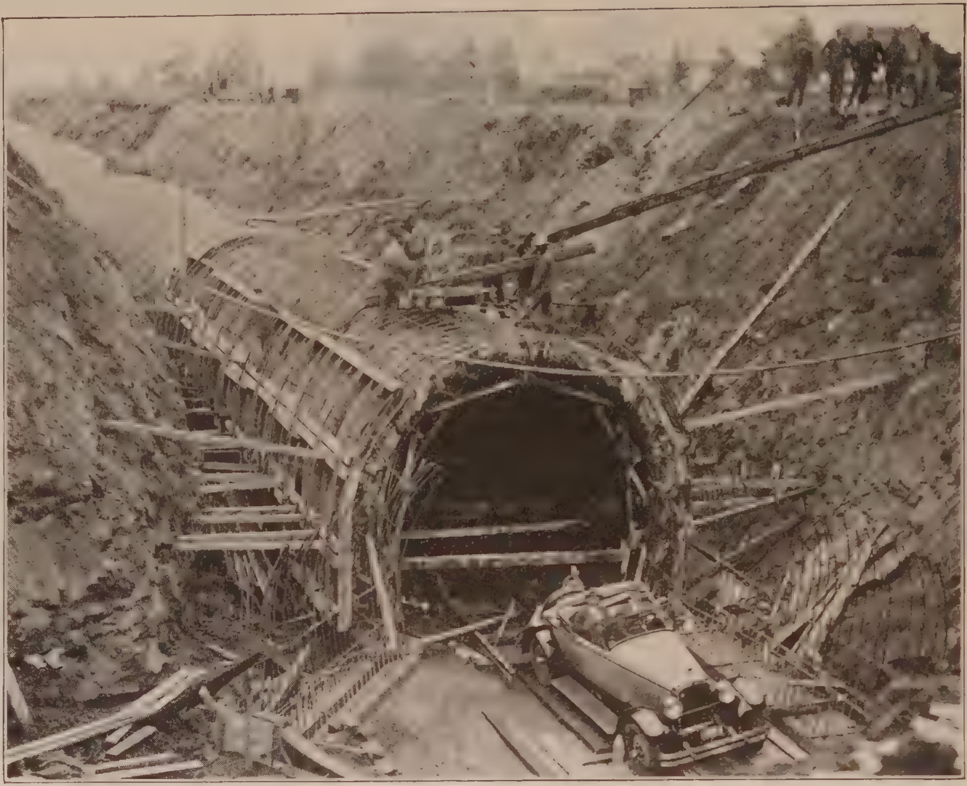
The monolithic section was divided into two units. The floor unit was built, finished and cured before the upper unit was concreted

When the inside forms had been completely assembled, the lower section of the exterior forms was put in place and the concrete placed in the lower side. Section by section the concrete was carried up, the reinforcing for the top being tied to the reinforcing of the lower side as the forms were carried upward. A detachable section of chute was held by the men to guide the concrete from the mixer chute to position above the forms.



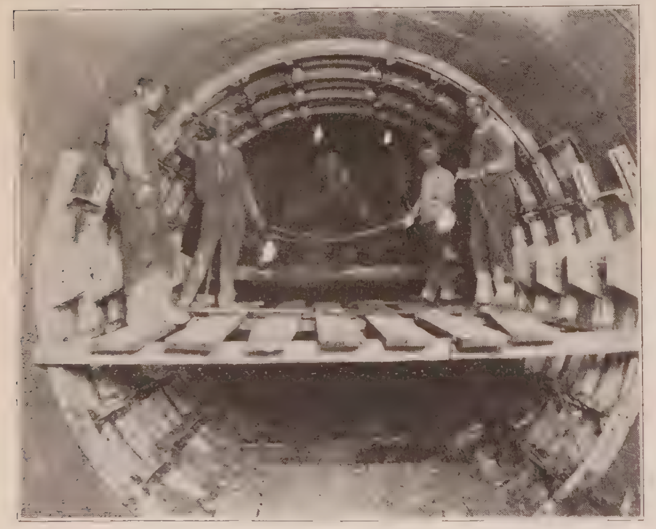
A special machine was used to erect and take down the forms inside the upper unit of the monolithic section

Included in this Royal Oak drain was more than 6 miles of tunnel, some of it 50 feet underground. Extremely treacherous patches of quicksand and high hills were encountered to complicate the job. Both brick and concrete was used to line the tunnel sections, depending upon the contract. Six shafts were used to connect the tunnel with the surface. One gang of men was engaged in timbering the tunnel and building the retaining wall. Another gang handled the boring operations at the head of the shaft.



The mixer was placed on the edge of the trench and the concrete was chuted directly into the forms

A narrow gauge railroad was used to carry the dirt to the nearest shaft where it was hoisted to the surface. The operations of boring and timbering the tunnel were carried on by the day shift. The night shift carried out the pouring of the concrete and in this way operations were carried on 24 hours a day.



A steel casing, which was used as a header in driving the tunnel, also served as the inside form for the tunnel section

Special steel headers were used for the men engaged in cutting out the dirt. The steel casing used in the header also formed the inside form wall for placing the concrete. As the head was pushed forward four or five feet, new sections of casing were put into position. The section was put into position and braced by the timbering gang so that the casing went ahead as rapidly as the dirt was removed from the head of the tunnel. On this job electrically operated knives were used to remove the dirt. One man operated this knife easily and as rapidly as the dirt was cut from the head, other workmen loaded the dirt into narrow gauge cars. Regular mine ventilation systems were employed to change the air in the tunnel. Between 450 and 500 men were employed in day and night shifts on the job.

Large as is the work being done in Oakland County, it is only a small part of the program to give the Detroit metropolitan area an adequate system of sewerage and storm water drainage. The entire system covers Wayne, Oakland, Washtenaw and Macomb counties and when completed as now planned will cost more than $35,000,000. This figure is divided as follows—Wayne County, $12,200,000; Oakland County, $14,000,000; Macomb County, $7,000,000, Washtenaw County, $2,250,000.

Fall Trade Fair Opens

The semi-annual international trade fair is being held from August 28th to September 3rd at Leipzig, Germany. The seven thousand exhibits now include a great variety of industrial products, prepared to appeal to American demands. Admittance is by invitation and every facility for examining the exhibits and transacting business is offered.

The 1927 Spring Fair surpassed all records for size and variety of exhibits and attendance.

Steam Curing of Concrete Products

The Effect of Hot Water Vapor on the Rate of Setting of Portland Cement Mortar Reported by an Investigator After an Interesting Series of Tests

By A. L. MILLER
Assistant Professor of Civil Engineering, University of Washington

IT is generally recognized that the "steam curing" of concrete products hastens their acquisition of strength. There appears to be very little information on the exact effect of this method of curing. This paper is a brief report of the results of a series of experiments recently performed in the Concrete Laboratory of the University of Washington and, it is hoped, may serve in a small way to add to the scant store of information now available on the subject.

The investigation may be correctly said to have covered the effect of the application of water vapor at temperatures between 125° F. and 212° F. on the strength of a mixture of portland cement, sand and water during the first eight hours after mixing. The term "water vapor" instead of "steam" is used because, accurately speaking, steam does not exist at atmospheric pressure at a temperature of less than 212° F. What is ordinarily referred to as steam should be more properly called water vapor, which is a mechanical suspension of minute particles of water in air.

The Test Procedure

The procedure of this investigation was as follows:

Three hundred and sixty specimens of a 1:3 proportion by weight of cement and sand were prepared in four groups of ninety. Sufficient water was added to permit the formation of the specimens in much the same manner as concrete products. The water-cement ratio was 0.67. The specimens were cylinders, two inches in diameter and four inches in length. The cylinders of each group were made as nearly simultaneously as possible by tamping in brass molds on steel pallets. The molds were immediately removed. A series of each group was placed in the water vapor at hourly intervals from one to seven hours. Three cylinders of each series were removed from the heat at hourly intervals and tested in compression.

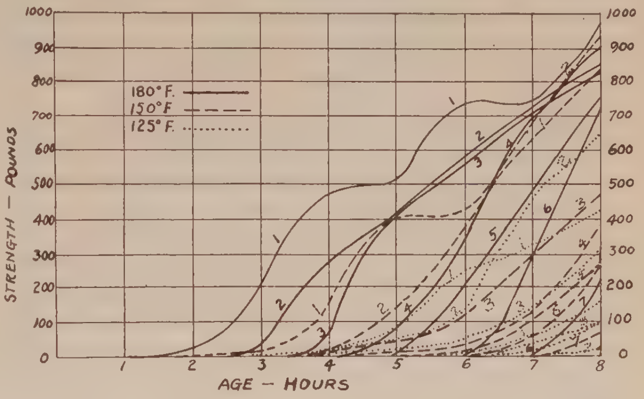
The temperature was obtained by introducing free steam into a fairly tight concrete steam chest and was recorded continuously by a recording hygrometer, the two bulbs of which were placed at extreme corners of the compartment. The recorded temperatures were constant except for variations caused by opening the door to introduce and remove the specimens. A relative humidity of 100 per cent was maintained at all times. Four ranges of temperatures were used, 125° F., 150° F., 180° F., and 212° F.

The procedure outlined was followed in order to study the two vital elements of the treatment at a given temperature, namely, the effect of the age of the specimen when placing in the heat and the relative effects of various lengths of time of treatment.

Results of the Tests

In view of the brief nature of this report the results are more clearly and concisely explained by omitting any attempt at a verbal explanation and relying entirely on accompanying chart. This chart presents the relation of the strengths to the various conditions and periods of treatment. The vertical scale is in terms of the total compressive strength of the cylinders in pounds. The horizontal scale gives the age of the specimens reckoned from the time of mixing.

The points represent the strongest specimen of each set of three. The reason for comparing the maximums rather than the averages is that experimental errors tended to underrate the strengths. Limited time and the impossibility of capping the cylinders introduced the most considerable errors. A comparison of the means would give almost identical results except for a few points in which the experimental error is very evident. Since these results are intended for comparison only and no attempt will be made to express them in terms of unit stress, this method of analysis seems justified.



The effect of hot water vapor curing on the setting of portland cement concrete, similar to that used in the manufacture of concrete products, is indicated by this chart

Three sets of curves appear on the chart, representing temperatures of 125, 150 and 180 degrees. The fourth group, that for 212 degrees, is omitted for reasons which will be stated later. The curves of each set are numbered according to the ages of the specimens at the time of placing in the heat.

Visible Physical Results

The visible results are of particular importance. It was originally intended to place a series of each group in the heat immediately after making. This was tried at 212 degrees and 125 degrees, with the result that the cylinders disintegrated within the first 15 minutes in the water vapor. The disintegration was due to two causes.

First—The cold specimens placed in a condition of higher temperature and 100 per cent relative humidity slumped considerably due to the condensation of moisture on the cold material. The additional moisture was sufficient to decrease the consistency to such an extent that the cylinders could not support their own weights.

Second—The sudden increase in temperature caused the cylinders to expand quickly and unevenly producing diametrical cracks extending throughout the length. At ages up to six hours, the 212° group developed these cracks. Tests of these specimens showed such wide variation that they should not be considered in this report. At 180° cylinders treated at the age of one hour showed slight cracks. None of the other series was visibly affected.

Age at Curing

An examination of the curves marked "One" reveals a striking similarity. Their irregular shape would seem to indicate that the application of heat to specimens one hour old either produces deleterious physical effects which are not visible or a derangement of the normal order of progression of the chemical reactions.

Specimens placed in the heat at an age of two hours or more acquired strength at a fairly regular rate. The rate appears to increase as the age of the specimen at the time of beginning the treatment increases. Attention is called to the slight irregularities in the curve for the 180° groups for two, three and four hour specimens. These variations are probably caused by the same factors as affected the one hour specimens, only to a much less extent.

For the acquisition of a given strength at a given temperature, the length of treatment is subject to a wide variation depending on the age at which the treatment was begun. The older specimens acquire strength in a much shorter period than the younger ones.

For a given cylinder, and in the range between 125° F. and 180° F., the higher the temperature the more rapid is the development of strength. The difference between 125° and 150° is more marked than that between 150° and 180°. The advantage of 180° over 150° is much less than the advantage of 150° over 125°.

Cylinders left at room temperature did not possess sufficient strength at the end of eight hours to record on the testing machine. They failed under a load of less than 20 pounds.

Conclusions

In most industries, the direct application of laboratory experiments to commercial practice should be undertaken with considerable discretion. To see the work just outlined directly applied in the operation of concrete products plants is not the intention of this report. It is hoped, however, that this work may serve as a basis for further investigation in a more practical way. The practical advantages of more rapid curing are too well known to be mentioned here.

The following general conclusions seem justified:

1. The use of hot water vapor for curing during the first eight hours has a very marked effect on the rate of hardening. It is possible that a proper application of heat and humidity will result in a more efficient production of concrete products.

2. A temperature of 212° F. should not be applied to concrete products less than eight hours old. Whether or not it is advisable to use this temperature on older specimens should be a subject of further investigation.

3. Warm water vapor should not be applied to specimens less than two hours old.

4. The older the specimen the more rapid is the increase in strength for a given treatment.

5. Up to 180°, the higher the temperature, the greater is the increase in strength in a given time. The relation of the increases has been previously noted.

Other Points

In conclusion, a number of important points not directly indicated by the results of this investigation, should be called to your attention.

1. The requisite strength of a given product to resist handling should be determined. In this experiment, cylinders with a compressive strength of over 300 pounds could be safely handled, while those over 600 pounds withstood a surprising amount of rough treatment. Obviously, the strength of the concrete in drain tile and building blocks, for example, would not be the same to permit handling.

2. The removal of the specimens from the heat is followed by a sudden drying out. Recent reports indicate that if the lost moisture is replaced within a reasonable time no damage is done.

3. It must be borne in mind that the relative humidity should be 100 per cent if possible during this stage of the curing.

4. Probably a more pronounced effect will be noted in the case of products with relatively thin walls, while the reverse will be true for more massive pieces.

5. A study of the effect of curing in hot water vapor on the final strength of concrete is advisable. I have recently received a confidential report on a series of tests which indicates an ultimate final strength as much as 30 per cent less than that of untreated specimens. I do not vouch for the correctness of the results nor the procedure but in my opinion a serious question is raised.

School Building Costs in Buffalo

School buildings in Buffalo of the reinforced concrete structural frame type vary in cost from 30 to 45 cents per cubic foot of volume. This range is due to the fact that the figures include construction costs for four different types of school buildings. According to Ernest Crimi, architect for the Board of Education of Buffalo, the costs for these types are as follows:

For three-story reinforced concrete skeleton buildings, an average of 30 cents per cubic foot.

For two-story structures of the same design, made up entirely of class rooms, from 40 to 42 cents per cubic foot.

Two-story schools of the design in which a gymnasium and auditorium are included, an average of 37 cents per cubic foot.

For 16-room and 20-room additions of reinforced concrete skeleton construction, from 35 to 45 cents per cubic foot.

These are actual construction costs, based on the volume of the structures. They do not include architects' fees or equipment.

The board has used the reinforced concrete skeleton type of construction exclusively since 1919, when the major building program was started. This type of structure meets all building code requirements for fire-safety and lateral resistance to wind pressure.

The building of these schools has been carried on under the direction of Mr. Crimi and James F. Gill, structural engineer for the Buffalo Board of Education.

Ornamental Products Plant Sold to Benedict Stone

The Benedict Stone Corporation has purchased the plant of the Linthicum Stone Corporation, Baltimore, Maryland, and plans either to enlarge the present plant or to erect a new 600 by 60 foot plant. The cost is estimated at $70,000.

Construction Section of Safety Council to Meet

Sumner Sollitt, President of the Associated General Contractors of America, will deliver the address of welcome to members of the Construction Section of the National Safety Council at the sixteenth annual safety congress at the Stevens Hotel, Chicago, on Tuesday morning, Sept. 27.

Major W. R. Richards, Field Secretary, Associated General Contractors, will speak on "The A. G. C. and Safety."

There will be a special session for new members who will learn how older men in accident prevention activities have organized jobs for safety work. Thomas E. Bentley, of the A. Bentley & Sons Co., will dwell on "Safeguarding a Job." George Opp, safety engineer, Detroit Edison Company, will emphasize "Keeping Out of the Rut in Safety Work." A timely address will be delivered by E. C. Harding, of the Ferro Concrete Construction Co., who is chairman of the section.

Gold Filled Concrete Pavement for Colorado

Gold-filled concrete for gold field pavement is the latest development from Colorado where a five mile stretch of Federal pavement has just been completed north of Colorado Springs in which the concrete contains something like $3,000 worth of the precious yellow metal to every mile.

This unusual concrete mixture was adopted by the Colorado engineers not with any idea of faster spending of the state funds or of imitating the pavement specifications outlined in the book of Revelations but rather with the idea of pure economy since it was found more economical to build the pavement with the gold in it than to construct it in any other way.

This peculiar situation came from the fact that the best coarse aggregate available for the job consisted of the crushed rock from the ore dump of the gold mines in the Cripple Creek district. These tailings assay something like $1.50 per ton which is not quite enough to warrant the expensive operations necessary for the removal of the gold but in no way interferes with the quality of the concrete.

The J. L. Brusselle Company of Colorado Springs probably had no difficulty getting men to work on the job although there were no reports of any of the crew plucking a shining nugget out of the skip of the big MultiFoote Paver with which the concrete was laid.

Government Specification for Masonry Cement

A government master specification for masonry cement has just been issued by the Federal Specifications Board.

Fineness: The residue on a standard No. 200 sieve shall not exceed 20 per cent by weight. Cement shall not be rejected for failure to meet this test if, after drying at 100 deg. C. for one hour and resieving, it meets this requirement.

Time of Setting: The neat cement paste, mixed to normal consistency, shall not develop initial set in less than 45 minutes as determined by the Vicat needle, or 60 minutes as determined by the Gillmore needle. Final set by either method shall be attained within 48 hours.

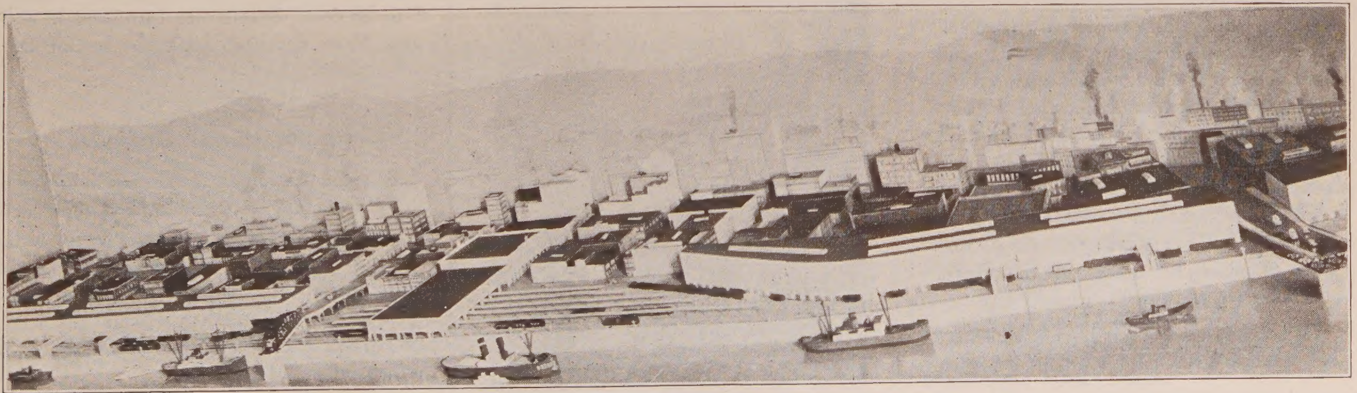
Soundness: Pats of neat cement, after being stored for seven days, one pat in laboratory air and one pat in water, shall be firm and hard and show no signs of distortion, cracking, or disintegration under both conditions.

Strength: The average compressive strength in pounds per square inch of not less than three 2-inch cubes, made of mortar composed of one part cement and three parts sand by weight, shall not be less than 175 at the age of seven days.

Plans Made for Harbor Development at Portland, Oregon

Work has been started on Portland's (Oregon) $2,000,000 concrete seawall, which will contain 65,000 cubic yards of concrete and is a unit of an $11,000,000 waterfront building program to be completed in 1929. Extending from Jefferson street, north to Glisan street, about a mile in length, it comprises part of Portland's extensive waterfront shipping district on the west side of the Willamette river. The erection of the seawall will mean the wrecking of old buildings, and docks that are an eyesore to the city, and the construction of modern buildings and ship-moorings, all of concrete. It is also claimed that property adjoining the seawall will have an assessed valuation of $22,000,000.

To make up this mass of concrete, other materials in proportion will be used. It will take 15,000 feet of lumber for the cradle work alone, and will be necessary to dredge 1,000,000 yards of fill from the bottom of the Willamette, to be used on the harbor side as a bulwark, against any spring floods that may come. The wall-proper, of reinforced concrete, will rest upon timber piling, rising 32 feet 5 inches above low water. It is to be 18 feet wide at the base, and 7 feet 7 inches at the top. The top of the wall is to be occupied by an esplanade, 25 feet in width where spectators may enjoy the river scenery, and the annual boat races and regattas that are put on during the June Rose Carnival.



An architect's conception of the completed concrete sea wall

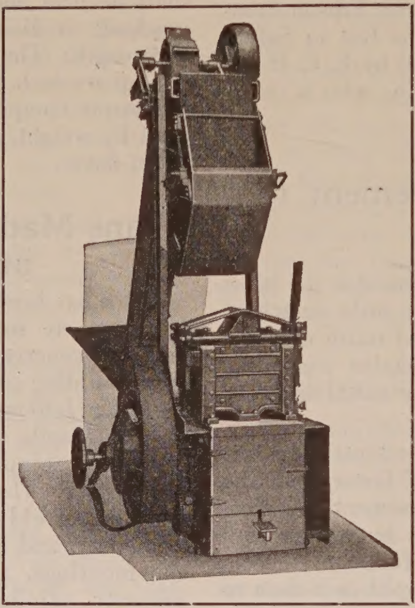
New Equipment

No Change Necessary in Multiplex Stripper for Face Block

The Multiplex Concrete Machinery Company, Elmore, Ohio, has put the finishing touches to its new single power press stripper, a production machine for any unit with few changes of the mold box. Block edges are made sharp and perfect.

Specially arranged cams force the concrete to become uniform when the tamp comes in contact with the material. The block are pressed top and bottom to a uniform density.

Working with mixed material, two men can make approximately 1,200 8x8x16 plain block per day. No change of the mold box is necessary for face blocks of the same size, the only change being a special filling attachment. Two 4x8x16 solid blocks can be produced at each operation by removing cores from the mold box and replacing the tamps.



"Speed King" Mixer Pours Into Forms

The new Jaeger "Speed King" mixer saves the wages of a wheeler by pouring concrete into forms and moving with the work like a paver. It requires only 6 feet of street space with loader. It is all-steel and roller-bearing equipped. The mixer is an end discharge type, with all the advantages of side discharge. For the sake of portability, it is also a trailer type and can be lifted by one man. A Ford truck is sufficient to tow it.

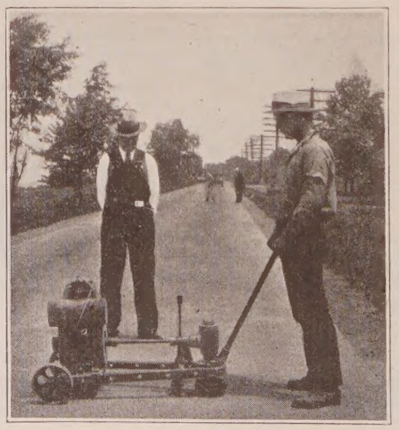
The mixer is built in low charger or loader type with water tank. The loader has the patented "Skip Shaker" to eliminate pounding on skip to unload. Inexpensive traction for moving itself along the forms, known at the Batch Meter, and swinging spout, can also be furnished for road or sidewalk contractors. The Jaeger Machine Co., 522 Dublin Avenue, Columbus, Ohio, manufactures the mixer.

Portable Highway Surfacing Machine Perfected

Several men using hand tools are replaced by a new machine that the Concrete Surfacing Machinery Company, Cincinnati, Ohio, has perfected for removing high spots in concrete roads and leveling repair spots.

The machine consists of an air-cooled gas engine mounted on a chassis, and connected to a cutter head operated by bevel gears carried on Timken roller bearings. The chassis is mounted on two wheels with a third swivel disappearing caster on the front end which, with a touch of the foot, can be placed in operation. The outfit can thus be hauled from place to place by means of the swivel caster and truck wheels.

The cutter head is easily removable for the replacement of worn-out cutters. Since two cutter heads are supplied with each machine, one is always ready for operation while the cutters in the other are being replaced.



Notes from the Field

Hume Engineer

Mr. J. A. Dunn has been appointed chief engineer of the *American Hume Concrete Pipe Company,* the licensees for America of the Australian Hume developments. Mr. Dunn succeeds Mr. W. D. Kimmel, who resigned to take over the management of the *Detroit Concrete Hume Pipe Company,* Michigan licensees for the Hume process.

Blaw-Knox Absorbs Firm

The Blaw-Knox Company, with general offices at Pittsburgh, Pennsylvania, has purchased the *Milliken Brothers Manufacturing Company* of New York. The consolidation is effective September 1st.

The latter firm produces transmission towers, radio towers and standard steel buildings. Much of its business has been in the export field and the present Milliken organization will continue its work in that field and in addition will manage the export business of all Blaw-Knox products.

The Blaw- Knox Company will continue with its present organization to handle domestic business and the acquisition of the Milliken Company will make no change in this line. The manufacture of all products will be concentrated at the Blaw-Knox Company plants at Pittsburgh and Baltimore.

Industrial Literature

Pump Literature

A four-page folder published by the *Novo Engine Company,* Lansing, Michigan, gives a few facts about a new pump, No. 61-0, designed to handle profitably 50 to 10,000 g. p. h. and at heights from 1 to 20 feet. Details are furnished in the new *Novo* pumping book, to be off the press shortly.

International Bulletin

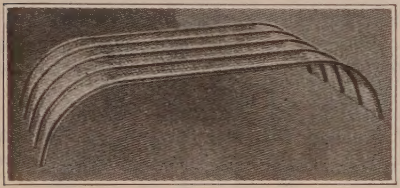
The International Cement Corporation's Bulletin 16, for July, contains a short description of the new Lousiana cement mill, one of a Massachusetts clapboard house built entirely of concrete, and items concerning the Galveston sea wall for flood prevention and several new dwellings and industrial buildings.

New Equipment

Stay-Rib Lath Serves Several Purposes

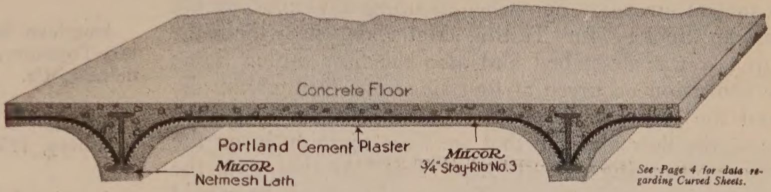
Using the basic principles of their metal lath used successfully in the field for plastering, engineers of the Milwaukee Corrugating Co. have succeeded in perfecting a ¾-inch Milcor Stay-Rib lath No. 3 that may be used as reinforcing in concrete construction of floors and roofs, and as a solid partition, without upright channels or studs. Due to its ability to hold wet concrete, the lath may be used as a form. Its reinforcing qualities commend it for use in span roof construction. Lack of unnecessary solid ribs and the position and shape of the metal mesh help to establish a remarkably strong bond between the concrete and the lath.

Its uses in floors and roofs are varied. The lath may be curved to a single arc, or curved at each end and flat in the center, for bridge-type floors. It is useful also as the reinforcing material for the concrete bases of terrazzo, tile, or wood finish floors, over wood joists or beams, over steel I-beams, metal lumber or patented bar joists and trusses. It is adaptable to pitched, saw-tooth, and monitor type roofs.



In wall construction, its heavy ribs give sufficient rigidity and stiffness to preclude the use of stiffening channels. Forms are unnecessary, since the concrete can be spread to the desired thickness first on one side and then the other. The process is the same for solid partitions. The ribs of the lath run perpendicular to the floor, and are anchored there and at the ceiling with runner channels. The lath protrudes out far enough from the studs to make furring strips unnecessary.

A saving of 12 to 20 inches in floor space is effected with the use of the lath for 2-inch monolithic concrete non-bearing walls, partitions, sidings, curtain walls, etc., and the total cost is said to be about half of that of bulkier types of construction.



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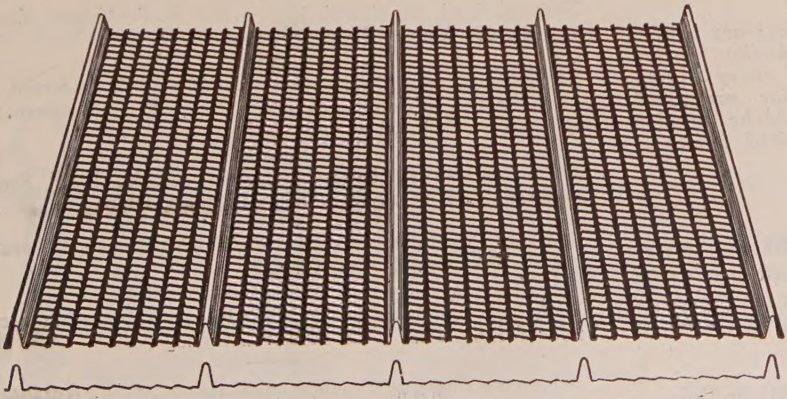
The uses of the lath will be found to be manifold. They include steps, railings, seat risers, stairways, galleries, tanks, water troughs, fireproofing of steel beams, and load-carrying steel columns, as well as for bridges, roadways and walks.

Practical engineering data gathered as the result of "breakdown" tests are shown in a booklet devoted to the lath. In each test data were secured to indicate the strength of the lath as formwork for carrying the wet concrete as well as reinforcement for the concrete after the slabs were cured.

Steel lumber supports were designed to carry the load of the floor slab and a live load sufficient to include the full strength of the construction. Four different brands of high rib lath were used. Conditions were maintained alike for all. A 1:2:4 concrete was poured 2½ inches thick on slabs measuring 4 by 8 feet, and cured for three weeks.

The slab containing the Stay-Rib lath was the only specimen able to take four times the designed load, and acted in accordance with the accepted laws governing the design of reinforced concrete. Its deflection when loaded with twice the designed load was about half the allowable. No failure occurred in the bond between the lath and concrete. Breaking occurred in the middle, due to simultaneous failure of both the lath and the concrete.

The Milwaukee Corrugating Company, Milwaukee, Wisconsin, manufactures the lath known as Stay-Rib No. 3.



No Nails Needed for Hollis Ties

A meritorious system of form ties, already popular in the East, eliminates all but a few braces and practically all nails. The ties are 2 inches wide and 9 to 90 inches in length, and machine made. Below the ribbon board on each piece of studding is placed a sufficient number of ties to have one more than the number of sheathing boards the wall is to be high. The tie is brought down on each piece of studding and heeled up at the end so that it will grip the ends of the studding.

The second layer of ties is brought down and a half length lath and one full length lath placed through the two ties on the outside of the sheathing boards on the opposite side of the form from the studding. A spreader is forced between the sheathing boards, completing one sheathing board section. When the third layer of ties is in place the spreaders are wedged against the sheathing board. Spreaders are removed as the concrete is poured. Spaces between sheathing boards can be easily closed by driving the sheathing boards down into place with a hammer, since they are not nailed to the studding. When the concrete is set, a hatchet is used to strip the forms.

Further detailed information may be secured from the Concrete Form Tie Corporation, 1707 First National Bank Building, Pittsburgh, Pennsylvania.

Mixer Musings

Reported by "Joe"—The Mixer Boss.

Most Assuredly, Old Thing

Dear Joe:

I HAVE read with great interest your recent musings, and wish with all speed to be enrolled as a member of the Guild of Certified Slump Testers.

I well remember my first introduction to the Slump Test some four years ago when reading a volume of the American Society for Testing Materials, in which the slump test was described and also the flow table. Some little confusion occurred at first since our fitting shop delivered the slump tester with the concentric ringed base plate of the flow table so that we were apparently on the way to performing the "Flowp" Test. At that date the 3 minutes' interval between filling and removing the mould was in vogue, and a timing experiment of my rather clumsy first attempts indicated that approximately that time was taken for me to clear away the surplus concrete from around the base. A very small amount of practice considerably shortened this period, and then we found the time limit abolished.

I feel particularly pleased in applying for membership to your Guild, since our company was one of the first, if not actually the first, in this country to give the Slump Test a good trial, and to spread the knowledge.

We have in this country a society known as the Ancient Order of Froth Blowers, life membership of which is obtained by the subscription of 5/-, of which about 1/6d. goes to charity and the balance provides the member with a badge in the form of cuff links and book of rules. The order would perhaps, for certain reasons, not be popular in America, but there is a rule which might be of interest to Slump Testers. Any Froth Blower introducing 25 other members is eligible for elevation to the superior grade of "Blaster." Perhaps you might consider this idea and form grades in Slump Testers.

I trust you will find the enclosed pamphlet and programme of interest, and with apologies for the length of the letter, I am,

Yours faithfully,
(Signed) J. E. WORSDALE,
Chief Chemist.
G. & T. Earle (1925) Ltd.
Wilmington, Hull, England.

(Assure all true Slump Testers that the necessary equipment and materials for membership in the Ancient Order of Froth Blowers be on hand locally, and every Slump Tester would be eligible for the superior order of "Blaster." The Order of Froth Blowers would be popular enough, if it were practicable. In the United States it would of necessity be a secret order.)

One fellow we talked to said that mud seams and honeycombing paid the same as solid concrete,—and didn't cost as much. A job settled on him, though, and now he has to dodge more and better inspectors. Maybe his cement went to his head.

Joe, the Mixer Boss.

Organizations

American Concrete Institute; Harvey Whipple, Secretary, 2970 West Grand Blvd., Detroit.

American Concrete Pipe Association; M. W. Loving, Secretary, 33 W. Grand Ave., Chicago.

American Construction Council; Dwight L. Hoopingarner, Executive, 28 W. 44th St., New York City.

American Engineering Standards Committee; Dr. P. G. Agnew, Secretary, 29 West Thirty-ninth St., New York City.

American Road Builders' Association; Chas. M. Babcock, President; Miss E. A. Birchland, Secretary, 29 W. 39th St., New York City.

American Society for Testing Materials, C. L. Warwick, Secretary-Treasurer, Engineers' Club Building, 1315 Spruce St., Philadelphia, Pa.

Associated General Contractors of America; D. H. Sawyer Secretary, 1150 Munsey Bldg., Washington, D. C.

Associated Metal Lath Manufacturers; 123 West Madison St., Chicago; Wharton Clay, Commissioner.

Building Officials Conference of America: H. E. Plummer, President; Fred W. Lumis, City Hall, Springfield, Mass., Secretary.

Concrete Reinforcing Steel Institute; M. A. Beeman, Secretary Tribune Tower, Chicago.

Concrete Products Association; S. I. Crew, President, Norwood, Ohio; Austin Crabbs, Secretary, Box 343, Davenport, Iowa.

Iowa Concrete Products Association; **Floyd Goodrich, President; R. L. Gavin, Secretary-Treasurer, 405 Hubbell Bldg., Des Moines, Iowa.**

National Association of Building Trades Employers; A. E. Coleman, President; A. W. Dickson, Executive Secretary. 2226 Builders Building, Chicago, Illinois.

National Association of Builders' Exchanges; William F. Chew Baltimore, President; Earl F. Stokes, Secretary, 15 East Fayette St., Baltimore, Md.

National Crushed Stone Association; J. R. Boyd, Secretary, 751 Earle Building, Washington, D. C.

National Housing Association; Lawrence Veiller, Secretary and Director, 105 East Twenty-second St., New York City.

The National Lime Association; G. B. Arthur, Secretary, 927 15th Street, N. W., Washington, D. C.

National Slag Association; H. J. Love, Secretary-Treasurer, 933 Leader-News Building, Cleveland, Ohio.

National Sand and Gravel Association; V. P. Ahearn, Executive Secretary, 432 Munsey Bldg., Washington, D. C.

Nebraska Concrete Products Association; A. V. Anderson, President, Reimers-Kaufman Co., Lincoln, Neb.; E. L. Bateman, Secretary, Bethany, Neb.

Ohio Concrete Products Association; G. M. Friel, Secretary Treasurer, 2284 North High St., Columbus, Ohio.

Portland Cement Association; William M. Kinney, General Manager, 33 West Grand Ave., Chicago.

Rail Steel Bar Association; H. P. Bigler, Engineering Secretary, Builders' Bldg., 228 N. La Salle St., Chicago, Ill.

Wisconsin Concrete Products Association; A. P. Kuranz. Secretary-Treasurer, 425 E. Water St., Milwaukee.